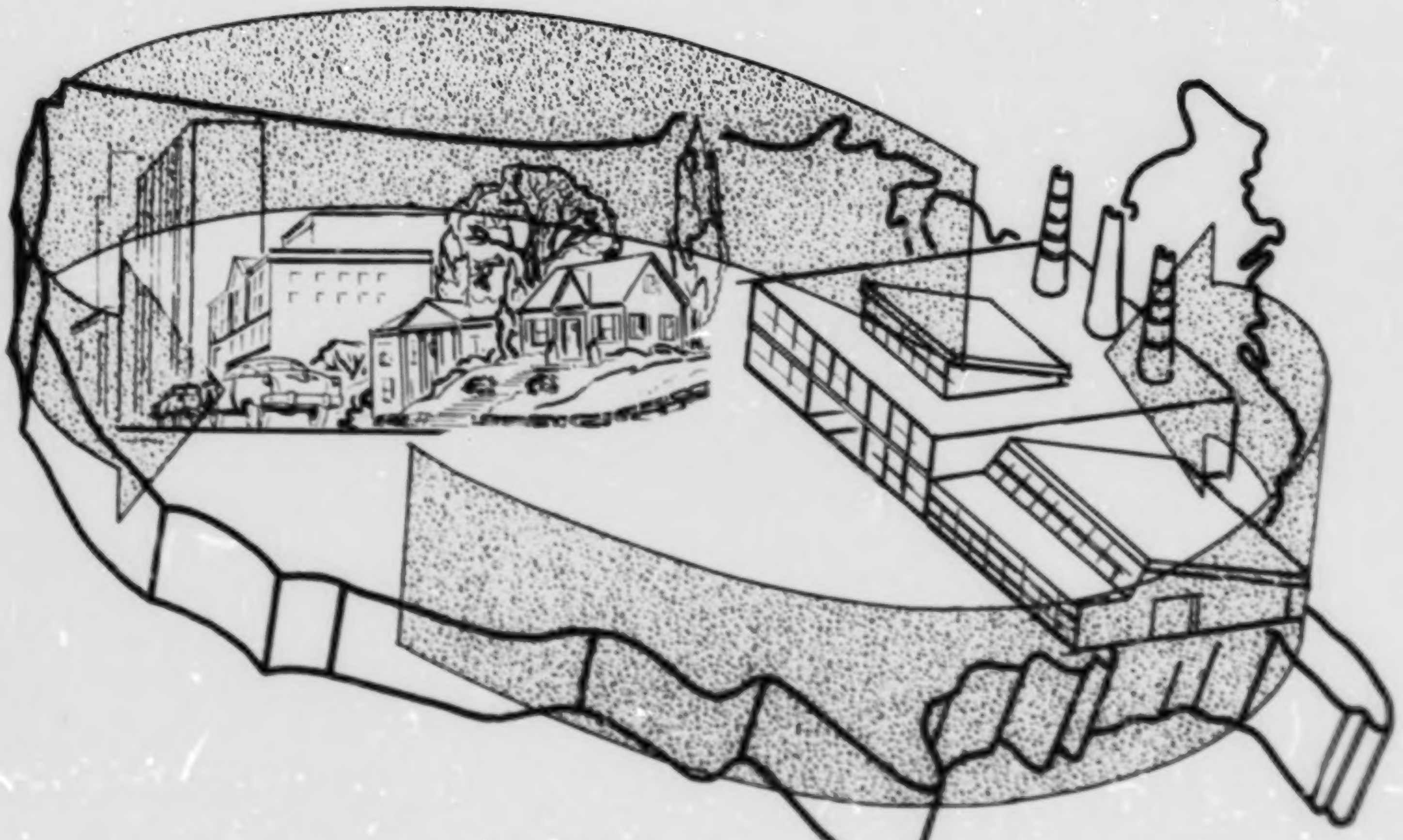
PB195159

# KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI AIR POLLUTION ABATEMENT ACTIVITY

## PHASE II. PRE-CONFERENCE INVESTIGATIONS



Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
March 1968

183

## KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI

## -- ERRATA SHEET --

Page 3 - Figure 1: Southern border of Wyandotte County missing.

Page 13 - Figure 6: Southern border of Wyandotte County missing.

Page 25 - last paragraph: tons/$mi^2$-mo. should read grams/$meter^2$-mo. in all cases.

Page 26 - Figure 11: units should be grams/$meter^2$-mo. instead of tons/$mi^2$-mo.

Page 56 - Table 26: station sources should read stationary sources.

Page 66 - second paragraph, second line: 84 percent should read 81 percent.

Page 70 - first paragraph, fourth line: solvents, vehicles, or raw materials should read solvents as degreasers, thinners, or raw materials.

Page 71 - Figure 14: designations for on-site open burning and on-site incineration should be reversed.

Page 87 - Table 39, Spring column, Inversion row: 22 should read 21.

Page 90 - first paragraph, second line: 6.4 mph, or about 2.4 mph should read 6.9 mph, or about 2.5 mph.

Page 112 - Figure 42: values should read
$\geq$10.0 grams/$meter^2$-mo.
$\geq$ 7.5 grams/$meter^2$-mo.
$\geq$5.0 grams/$meter^2$-mo.
$<$5.0 grams/$meter^2$-mo.

Page 113 - Figure 43: values should read
$\geq$10.0 grams/$meter^2$-mo.
$\geq$ 7.5 grams/$meter^2$-mo.
$\geq$5.0 grams/$meter^2$-mo.
$<$5.0 grams/$meter^2$-mo.

Page 115 - Figure 45: $>0.2$ mg $SO_3/100\ cm^2$-day should read $<0.2$ mg $SO_3/100\ cm^2$-day.

Page 116 - Figure 46: $<0.2$ mg $SO_3/100\ cm^2$-day should read $<0.3$ mg $SO_3/100\ cm^2$-day.

Page 150 - Figure C-1: Southern border of Wyandotte County missing.

Page 154 - $\frac{\text{Service station sales in county (\$)}}{\text{Service station sales in state (\$)}}$ X gasoline sales in state (gallons)

Page 167 - Reference 23: 1964 - 1190 should read 1964 - 1990.

Page 177 - STATION 023: HOLIDAY INN should read STATION 023: EAST KCK

9593

**STANDARD TITLE PAGE FOR TECHNICAL REPORTS**

1. Report No.
APTD 68-1

2. Govt. Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Kansas City, Kansas - Kansas City, Missouri
Air Pollution Abatement Activity
Phase II. Pre-Conference Investigations

5. Report Date
March 1968

6. Performing Organization Code

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Bureau of Disease Prevention and Environmental Control
National Center for Air Pollution Control
Cincinnati, Ohio 45227

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Agency Name and Address
Same

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes
The APTD series reports technical data of interest to a limited readership.

16. Abstracts

This report is based upon an investigation of air pollution conducted in the Kansas City area during 1966 and 1967. The report is intended to assist the governmental agencies concerned with such air pollution in their consideration of the following.

1. Occurrence of air pollution subject to abatement.
2. Adequacy of measures taken toward abatement of pollution.
3. Nature of delay, if any, in abating the pollution.
4. Necessary remedial action, if any.

17. Key Words and Document Analysis. (a). Descriptors

Air pollution
Abatement
Occurrence
Delay time
Aerosols
Exhaust emissions
Inventories
Meteorological data
Wind (meteorology)
Visibility
Turbidity
Sulfur oxides
Environmental surveys
Experimental data
Stability
Temperature inversions
Mixing
Metals
Sulfates
Seasonal variations
Sulfur dioxide
Sulfation
Periodic variations
Vegetation
Deterioration
Hydrocarbons
Carbon monoxide
Industrial wastes
Vehicles
Fuel consumption
Refuse disposal

17b. Identifiers/Open-Ended Terms
Kansas City, Kansas
Kansas City, Missouri
Kansas
Missouri

17c. COSATI Field/Group 13/02

18. Distribution Statement
Unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class. (This Page)
UNCLASSIFIED

21. No. of Pages
185

22. Price

FORM NBS-867(1-70)

# KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI
# AIR POLLUTION ABATEMENT ACTIVITY

## PHASE II. PRE-CONFERENCE INVESTIGATIONS

Prepared for Conference Use Only

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Disease Prevention and Environmental Control
National Center for Air Pollution Control

Cincinnati, Ohio
March 1968

This report is based upon an investigation of air pollution conducted in the Kansas City area during 1966 and 1967. The report is intended to assist the governmental agencies concerned with such air pollution in their consideration of the following.

1. Occurrence of air pollution subject to abatement.
2. Adequacy of measures taken toward abatement of pollution.
3. Nature of delay, if any, in abating the pollution.
4. Necessary remedial action, if any.

# CONTENTS

I. INTRODUCTION . . . . . . . . . . . . . . . . . . . . . . . . . . 1
History of Abatement Activity . . . . . . . . . . . . . . . . . . 1
Area Description . . . . . . . . . . . . . . . . . . . . . . . . 2
Climatology . . . . . . . . . . . . . . . . . . . . . . . . . . . 4
Project Design . . . . . . . . . . . . . . . . . . . . . . . . . 12
II. RESULTS OF COMPREHENSIVE SURVEY . . . . . . . . . . . . . . . . . 15
Particulate Pollutants . . . . . . . . . . . . . . . . . . . . . 15
Gaseous Pollutants . . . . . . . . . . . . . . . . . . . . . . . 27
Air Pollution Effects . . . . . . . . . . . . . . . . . . . . . . 33
Emission Inventory . . . . . . . . . . . . . . . . . . . . . . . 39
Meteorological Data - Representativeness of Sampling Period . . . . 86
III. POLLUTION IMPACT ON THE STUDY AREA . . . . . . . . . . . . . . . . 93
Pollution Roses . . . . . . . . . . . . . . . . . . . . . . . . . 93
Visibility Reduction . . . . . . . . . . . . . . . . . . . . . . 106
Turbidity Measurements . . . . . . . . . . . . . . . . . . . . . 107
Geographic Distribution of Pollutant Concentrations . . . . . . . . 108
IV. PARTICULATES AND SULFUR OXIDES EFFECTS AND STANDARDS . . . . . . . . 117
Particulate Pollution . . . . . . . . . . . . . . . . . . . . . . 117
Sulfur Oxides Pollution . . . . . . . . . . . . . . . . . . . . . 119
REFERENCES . . . . . . . . . . . . . . . . . . . . . . . . . . . . 121
APPENDICES . . . . . . . . . . . . . . . . . . . . . . . . . . . . 123
A. Phase I. Conclusions and Recommendations . . . . . . . . . . . . 125
B. Description of Project Design . . . . . . . . . . . . . . . . . 135
C. Aerometry Operation and Techniques . . . . . . . . . . . . . . . 143
D. Emissions Inventory Procedure. . . . . . . . . . . . . . . . . . 153
E. Pollutant Measurement Data . . . . . . . . . . . . . . . . . . . 169

# KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI
# AIR POLLUTION ABATEMENT ACTIVITY

## PHASE II. PRE-CONFERENCE INVESTIGATIONS

## I. INTRODUCTION

### HISTORY OF ABATEMENT ACTIVITY

A two-phase investigation of air pollution in the Kansas City Metropolitan Area was initiated on May 23, 1966, by the Public Health Service, U. S. Department of Health, Education, and Welfare, in cooperation with the air pollution control agencies of the States of Missouri and Kansas and several local agencies. The first phase of the investigation was concerned with the reduction in visibility from air pollution in the vicinities of the Kansas City, Missouri, Municipal Airport and the Kansas City, Kansas, Fairfax Airport. Following this first phase of the abatement activity and the subsequent abatement conference held in Kansas City, Missouri, in late January 1967, the Phase II part of the investigation dealing with the overall air pollution problem in the area was undertaken.

The official consultation concerned with initiation of the abatement activity is described in the Phase I report,[1] which was presented at the January 1967, session of the abatement conference. Recommendations of this session of the Conference are presented in Appendix A of this report.

This report describes the activities undertaken and enumerates the data collected during the Phase II investigations. It is for use in the second session of the Kansas City, Kansas - Kansas City, Missouri, Interstate Air Pollution Abatement Conference initially called by the Secretary of Health, Education, and Welfare on December 28, 1966. Authority for the interstate abatement action is provided by the Clean Air Act as amended (42 U.S.C. 1857, et seq.).

BLANK PAGE

Cooperating air pollution control agencies immediately concerned with the Phase II investigation were:

- Missouri Air Conservation Commission
- Kansas State Department of Health
- Kansas City, Missouri Health Department
- Independence, Missouri Health Department
- Kansas City-Wyandotte County, Kansas Health Department
- Platte County, Missouri Health Department
- Clay County, Missouri Health Department
- Jackson County, Missouri Health Department
- Cass County, Missouri Health Department
- Leavenworth City-County, Kansas Health Department
- Johnson County, Kansas Health Department
- Abatement Program, National Center for Air Pollution Control, Public Health Service

## AREA DESCRIPTION

### Topography

The Kansas City study area, covering approximately 3200 square miles, is composed of seven counties in two states (Figure 1). These are Platte, Clay, Jackson, and Cass Counties in Missouri and Leavenworth, Wyandotte, and Johnson Counties in Kansas. The terrain surrounding this area is relatively flat, open country, with an average elevation nearly 900 feet above mean sea level (msl). The only significant large-scale topographic feature near Kansas City is the Ozark Mountains in Missouri, about 75 miles to the southeast. This small range, with highest peaks of 2500 feet msl, has little influence on the Kansas City area. There is little change in average elevation northward from Kansas City to the Canadian Border or southwestward toward central Texas. To the east and the Mississippi Valley, the terrain slopes gently downward at about 1.5 feet per mile. Toward the west, the rolling plains of Kansas rise gradually as they approach the foothills of the Rocky Mountains.

Three shallow river valleys, dissecting the Kansas City area into four sections, complicate the generally smooth terrain. The Missouri River moves from west to east through the area and has formed a valley, which is 2 to 3 miles wide. The Kansas River and the Blue River, which flow into the Missouri from the southwest, have valleys that are 1.5 and 0.5 miles wide, respectively. The Kansas River joins with the Missouri River near the center of the area, and the Blue River does so 7 miles further east. The river bottomlands are at about 730 feet

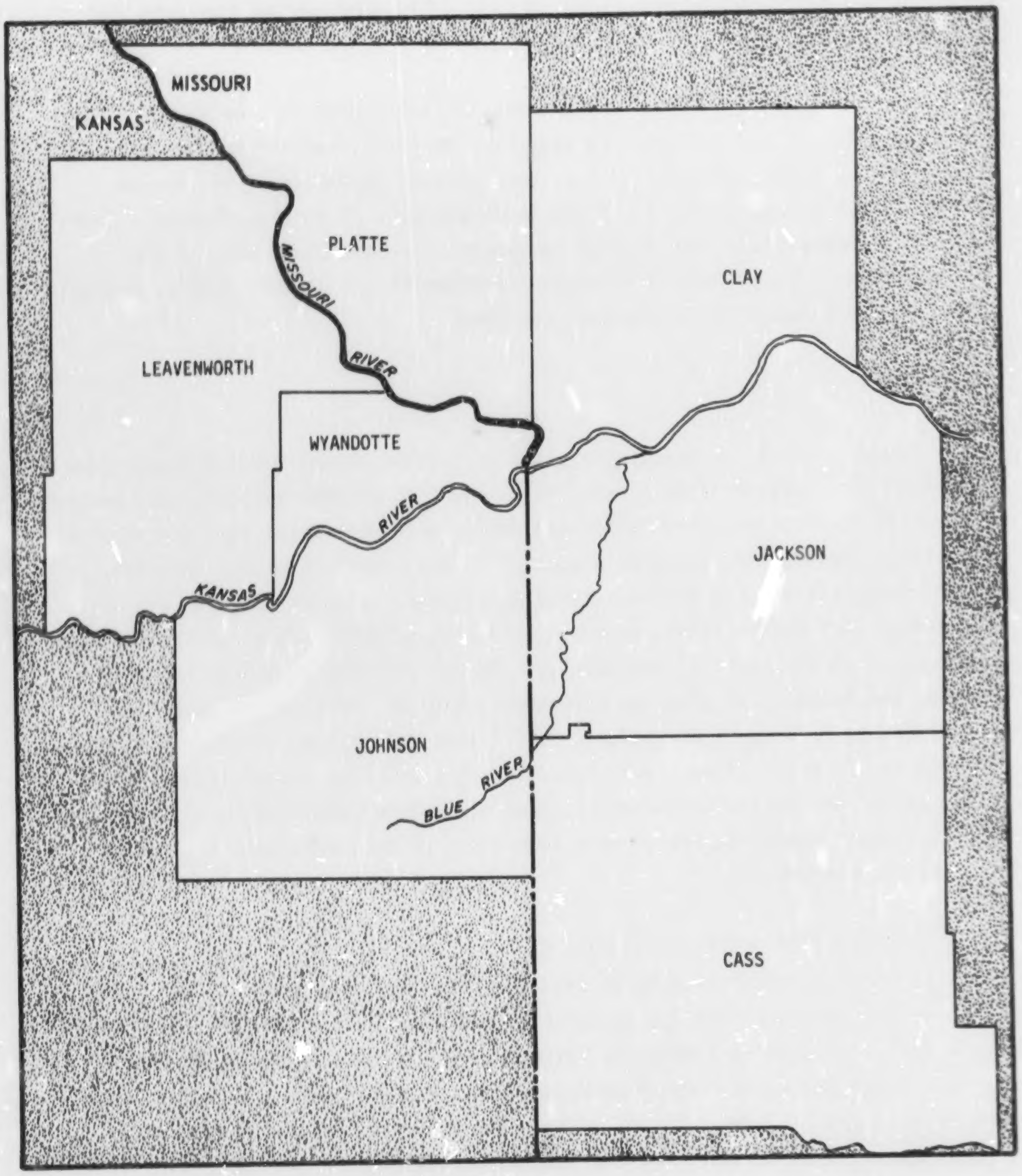

MISSOURI
KANSAS
PLATTE
MISSOURI RIVER
CLAY
LEAVENWORTH
WYANDOTTE
KANSAS RIVER
JACKSON
JOHNSON
BLUE RIVER
CASS

Figure 1. Kansas City study area.

msl; and, although the river valleys are shallow, in some places they are flanked by bluffs 200 feet high. These three river valleys are an important topographic feature since the major air pollution sources of the area - industrial plants, power generation facilities, and open-burning dumps - are located almost exclusively on the river bottomlands. The effects of valleys on the transport and dispersion of air pollutants are well documented.[2]

The three major business and residential areas that make up Kansas City are located out of the valleys. Kansas City, Missouri, and its suburbs are located south, north, and east of the confluence of the Missouri and Kansas Rivers; Kansas City, Kansas, is to the south and west of this confluence. Independence, Missouri, and some smaller communities are south and east of the Missouri River - Blue River confluence. Leavenworth and Olathe, Kansas, are two of the larger communities in the outlying area.

## CLIMATOLOGY

### General

The climate of the Kansas City area is typical of the Great Plains region. Since no natural obstructions hinder the movement of weather systems, cool masses of air from the west and north alternate freely with warm moist air from the Gulf of Mexico in controlling the area's weather. This situation allows frequent, and sometimes extreme, changes in weather conditions. As a result, the air mass stagnations that plague other regions by allowing accumulation of air contaminants seldom occur in this part of the country. In fact, in the 30 years from 1936 to 1965, the Kansas City area was affected by only one incident of an air mass stagnation, as defined by Korshover (1967);[3] that case lasted for 6 days and occurred in the month of October. Therefore, the relationship of sources to receptors and the individual meteorological elements of wind direction, wind speed, and atmospheric stability are of more importance to this area than are the occurrence of stagnations.

### Wind Direction, Wind Speed, and Stability

Valid climatological data on wind direction and wind speed in the Kansas City area are available for the Kansas City Municipal Airport and for the Richards Gebaur Air Force Base at Grandview, Missouri. The former is located in the Missouri River Valley near downtown Kansas City, Missouri, and the latter is on open terrain about 19 miles to the south. The Municipal Airport data are for the 10-year period 1951 to 1960, and the Grandview data are for approximately 9 years in the period 1954 to 1962.

Seasonal and annual wind roses for these two locations are presented in Figures 2 through 5. Note the difference in wind speed classifications; this is due to a difference in the handling of the raw data by the Weather Bureau and the U.S. Air Force. It can be seen from these wind roses that winds in this area are predominately from the southerly directions. This is especially true during the summer when south-southeast through south-southwest winds occur 35 to 40 percent of the time at both locations. However, for other frequently occurring directions, there is less agreement between the open terrain (Grandview) and the valley (Municipal Airport) locations.

At Grandview, the absence of any terrain effect is indicated by the smooth distribution of winds through the 16 directions. In contrast to this, the wind roses for the valley location at Municipal Airport have an irregular appearance, apparently due to terrain effects. For example, the number of occurrences of southeasterly winds at Municipal Airport are fewer and occurrences of southwesterly winds are greater than those at Grandview. These differences are accompanied by a higher frequency of northeasterly winds at the valley location, especially in the spring and summer months. The disparity in the frequency of various wind directions at the two locations seems to be due to a channeling effect of the valley. Bluffs and rapidly rising terrain are located within 2 miles of the valley airport to the southeast; also, the Missouri River Valley extends east-northeastward from this location. This combination seems to channel more winds along the river valley than would normally be expected. Channeling due to the Kansas River Valley, which extends to the southwest, also appears likely.

Because river valleys in this area channel the winds, simultaneous wind direction measurements made in the various valleys and on the high ground may not agree, especially in cases of light winds. There is a tendency for air contaminants emitted in a valley to be transported in a direction parallel to the valley sides. Contaminants therefore remain in the valley. Emissions on the open terrain are transported by the prevailing atmospheric airflow without the disruptive influence of topographic irregularities.

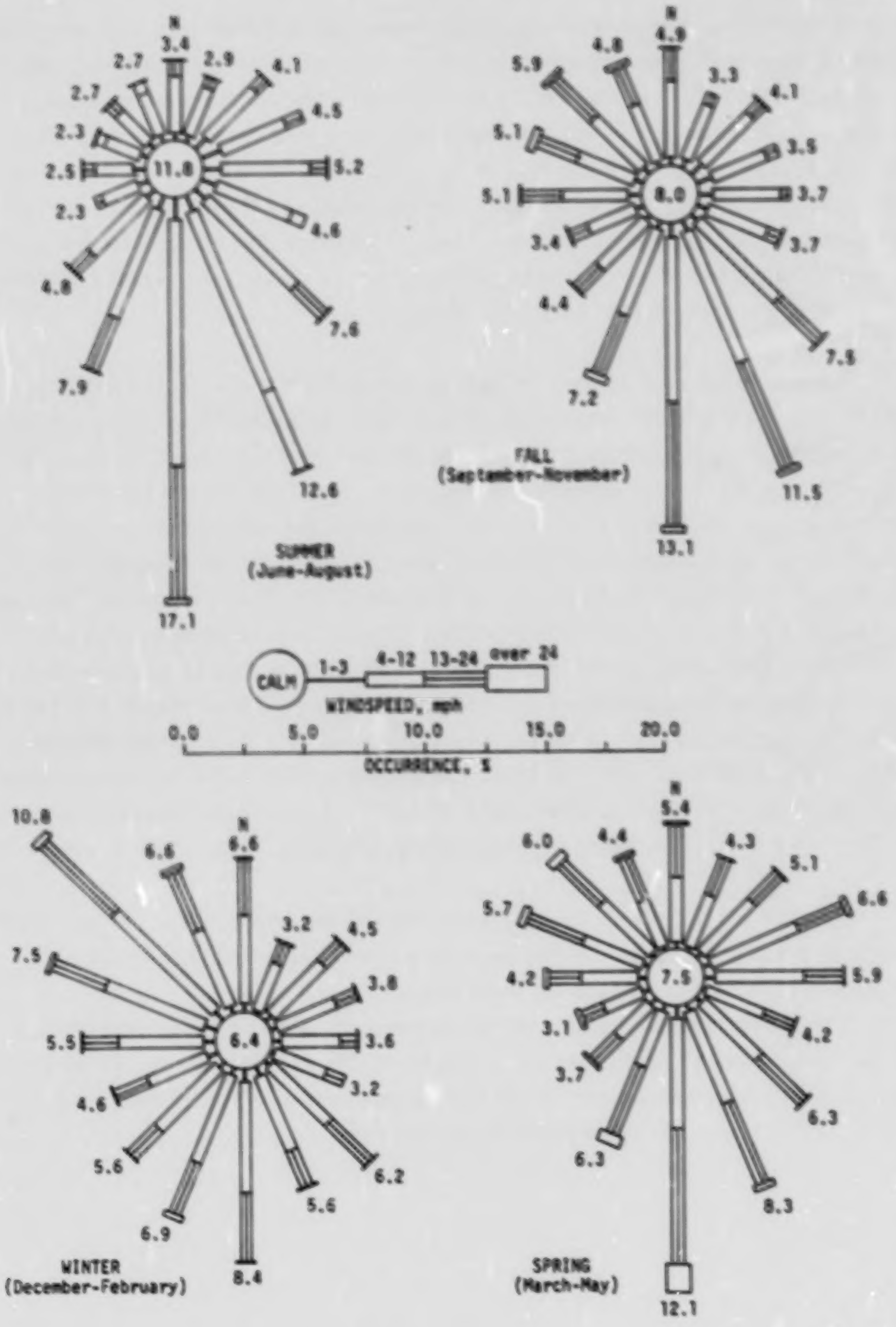


Figure 2. Seasonal wind roses for Richards-Gebour Air Force Base at Grandview, Missouri - 1954-1962.

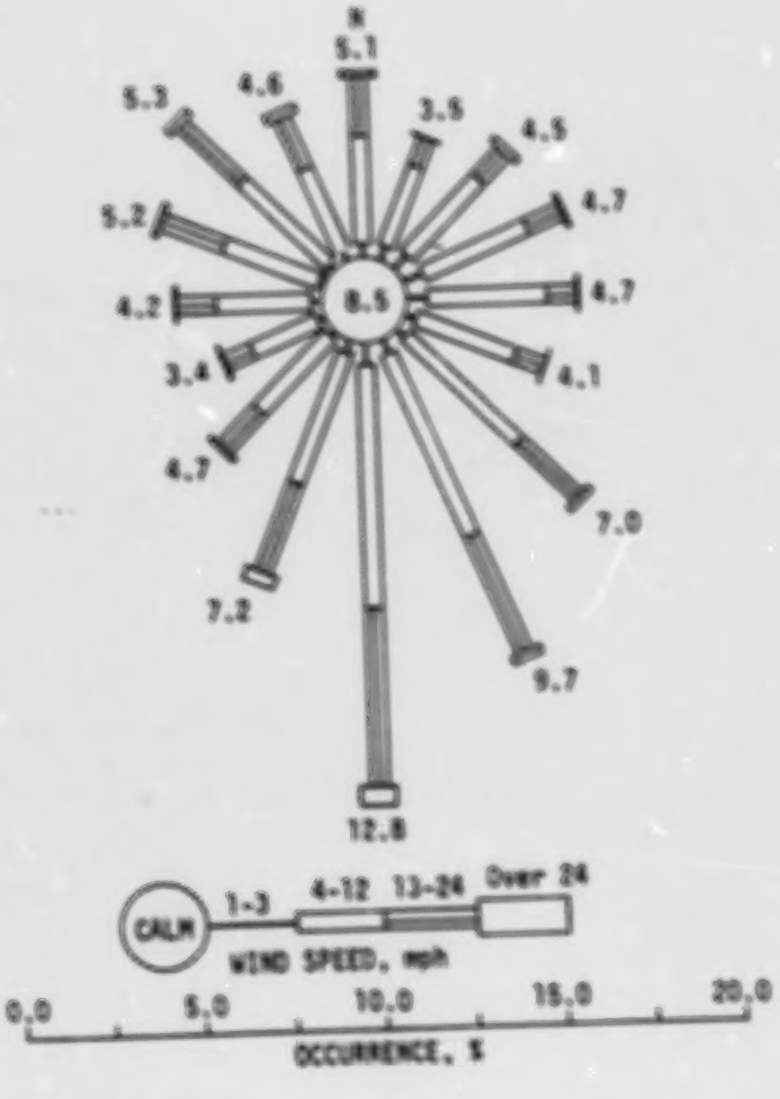


Figure 3. Annual wind rose for Richards-Gebaur Air Force Base at Grandview, Missouri 1954-1962.

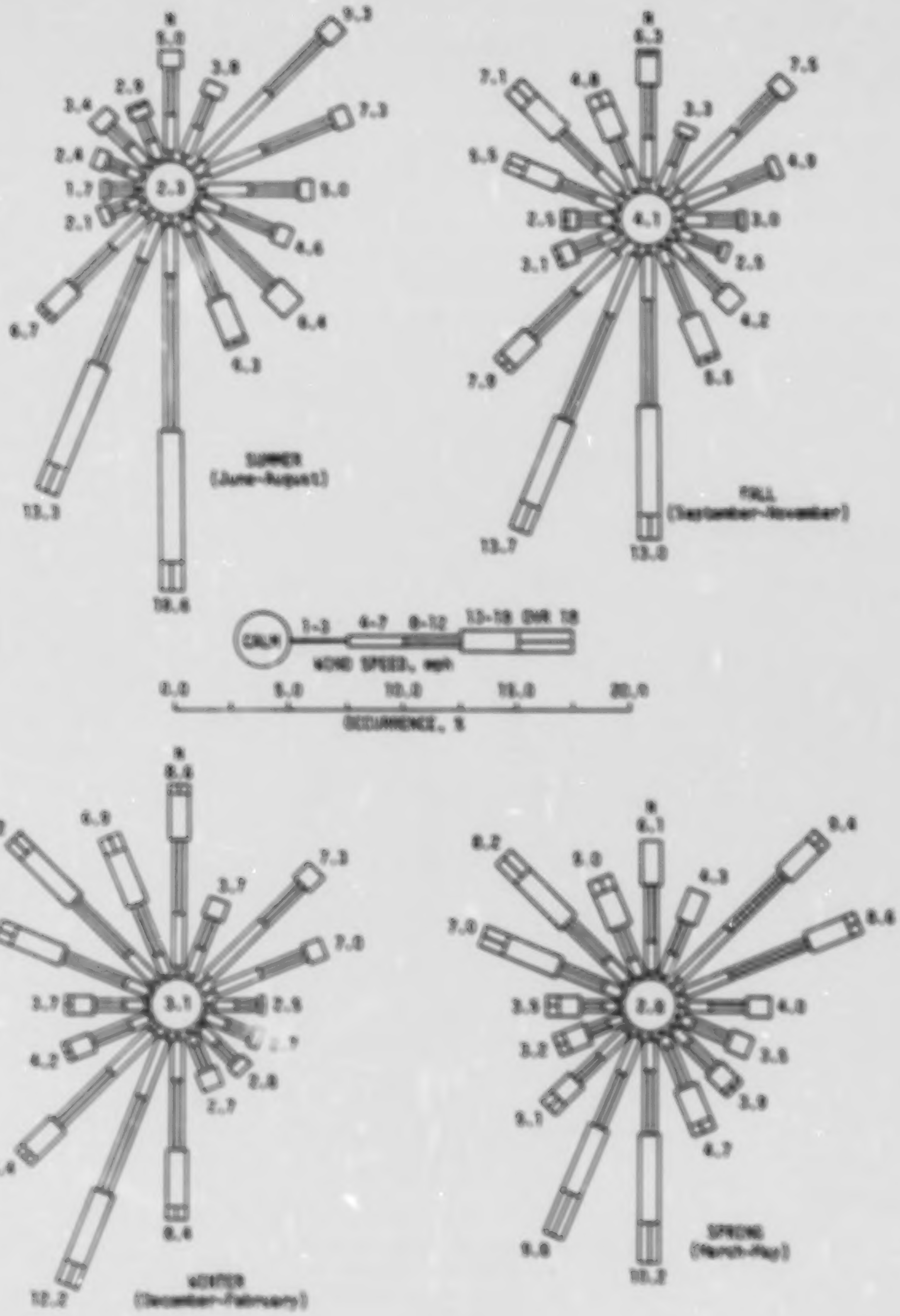


**Figure 4.** Seasonal wind roses for Municipal Airport at Kansas City, Missouri - 1951-1960.

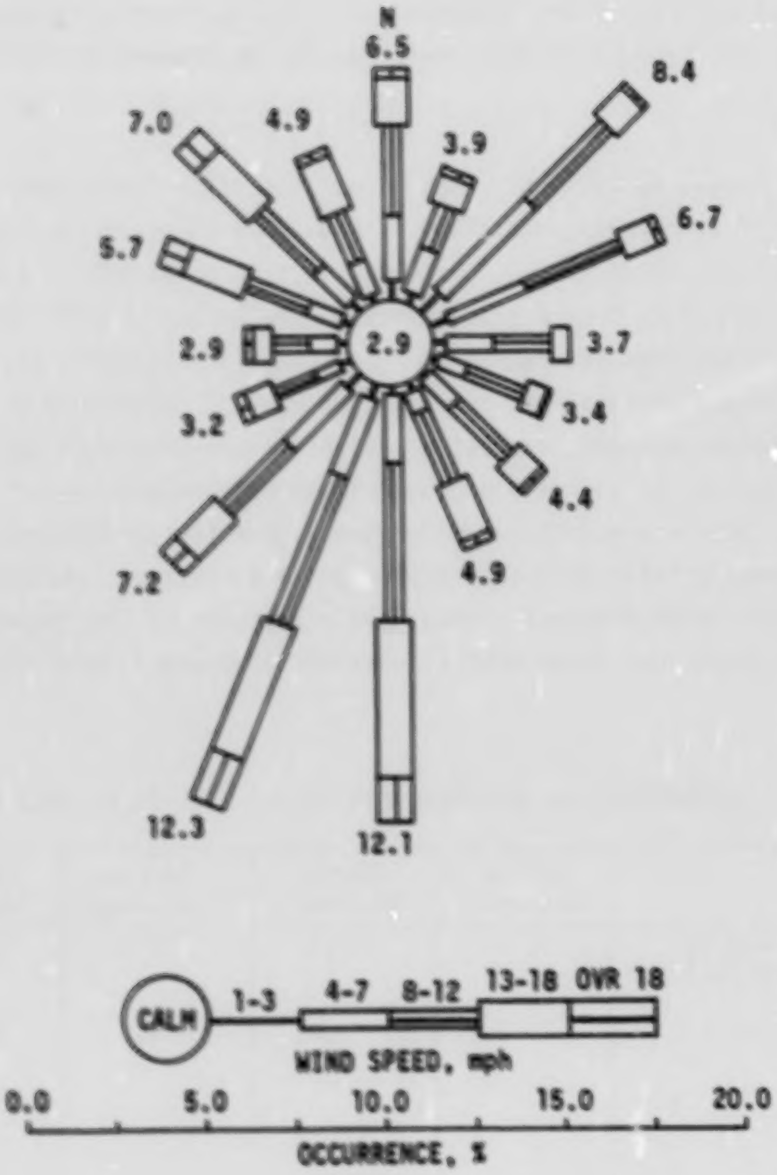


Figure 5. Annual wind rose for Municipal Airport at Kansas City, Missouri - 1951-1960.

Average annual and seasonal wind speeds for the Kansas City Municipal Airport and Richards-Gebaur Air Force Base at Grandview are given in Table 1. Although there are variations between the two, the annual averages for both locations are about 10 miles per hour. The valleys are pronounced enough to affect wind direction, but they do not significantly modify wind speed near the Municipal Airport. Generally, the greater the wind speed and the fewer the calms in an area, the better the dispersion of air contaminants. The observed wind speeds in the Kansas City area are typical of many locations in the Midwest and along the Mideastern seaboard.

A method suggested by Turner (1961)[4] was used to estimate the frequency of various classes of atmospheric stability from weather observations made at the Municipal Airport and at Grandview, Missouri, in the period 1961 - 1963. Combining these estimates with data from a study conducted by Hosler (1961)[5] that determined the frequency of low-level inversions at Topeka, Kansas (Hosler's study location nearest Kansas City), the seasonal percent frequency of occurrence of stability conditions (unstable, neutral, inversion) in the Kansas City area was estimated. Inversions, defined by an increase of temperature with height, are a typical nighttime condition. They are associated with poor dispersion conditions. Neutral stability is characteristic of cloudy and/or windy conditions, whether day or night, and is associated with moderately good dispersion in the atmosphere. The best dispersion conditions occur with an unstable atmosphere, characterized by

Table 1. CLIMATOLOGICAL AVERAGES FOR KANSAS CITY STUDY AREA LOCATIONS

| | Winter (Dec-Feb) | Spring (Mar-May) | Summer (June-Aug) | Fall (Sept-Nov) | Annua |
|---|---|---|---|---|---|
| Average wind speed at Municipal Airport,[6] mph | 10.1 | 11.4 | 9.8 | 9.9 | 10.3 |
| Average wind speed at Grandview, Mo.,[7] mph | 10.2 | 11.4 | 8.3 | 9.8 | 9.9 |
| Stability conditions,[5,8] % of time | | | | | |
| Unstable | 10 | 17 | 36 | 18 | 20 |
| Neutral | 50 | 55 | 26 | 37 | 42 |
| Inversion | 40 | 28 | 38 | 45 | 38 |
| Mean afternoon mixing depth,[9] meters | 800 | 1500 | 1700 | 1350 | 1350 |

sunny, warm days. The percentages given in Table 1 should apply to both valley and open terrain locations since the valleys do not notably affect stability.

The afternoon mixing depth (AMD) is a measure of the amount of vertical mixing that can take place in the atmosphere. For any single wind speed, the greater the mixing depth, the greater the volume of air available to mix with pollutants, and the lower the resulting pollutant concentrations.

Data presented by Holzworth (1967)[9] include seasonal mean AMD's for Columbia, Missouri, which should be applicable to the Kansas City area. As can be seen from Table 1, mixing depths are greater in the spring and summer than in fall and winter.

## Air Pollution Potential Climatology

If all the elements in Table 1 are considered together, an estimate of the times of year most and least favorable for the atmospheric dispersion of air contaminants can be made. Spring is the season of rapid weather changes, typified by strong wind, large AMD's, low frequency of inversions, and high frequency of neutral stability. This is the season of the year most favorable for dispersion. Although general weather conditions are somewhat less variable during the summer than during spring months, the high frequency of unstable conditions, large AMD's, and dissipation of inversions soon after sunrise make summer a season for good dispersion. In most respects, fall is considerably less favorable than other seasons for good atmospheric dispersion; it has low average AMD's, low wind speeds, and high frequency of inversions, all accentuated by a less-frequent passage of weather systems than occurs in the winter and the spring. Winter also is unfavorable for dispersion, but it has a frequent passage of weather systems. Short-period buildups of air contaminants may occur, but the buildup ends as the next uncontaminated mass of cold air pushes into the area.

Although it can be concluded that the fall is the least favorable time of year for the dispersion of air contaminants, it should be remembered that this is not necessarily the season when the highest $SO_2$ and particulate pollutant concentrations will be measured.

Emissions from heavy use of fossil fuels during the winter and early spring may more than compensate for the additional dispersing power of the atmosphere. The highest pollutant concentrations are therefore most likely to occur in the early months of the year.

## PROJECT DESIGN

Pursuant to the objectives and scope of the Kansas City, Kansas - Kansas City, Missouri Abatement Activity, a project was designed to fulfill the requirements presented below.

An air-quality-monitoring network, depicted in Figure 6, was established to determine the impact on receptor areas of primary area sources and point sources. The network was oriented with the wind directions usually encountered. A more detailed description of the network is presented in Appendix C.

An emissions inventory of sulfur oxides, particulates, hydrocarbons, and carbon monoxide emissions from industrial, commercial, governmental, residential, and mobile sources was conducted to:

1. Provide positive evidence of the existence of source emissions within the study area and define their locations, magnitudes, and relative contributions of pollutants.
2. Provide data for calculations that would demonstrate whether interstate transportation of pollutants occurs and the magnitude of impact of any such emissions at selected receptor sites.

Rapid survey techniques similar to those described in the Phase I technical report were employed to provide a zone-oriented presentation. The boundaries of the 21 zones of the Phase I report remained the same. An additional 49 zones were selected to cover the remainder of the Phase II study area. A detailed description of the procedure is included in Appendix D.

A system for collecting meteorological data representing river lowlands and higher elevations in the area was established. The system provided surface wind and other routine observations necessary for interpretation of the air-quality-monitoring data. The meteorological data were also used to determine the "representativeness" of the sampling period relative to past years.

A data-processing and analysis system was established to coordinate the acquisition of all types of data generated or collected during this activity and to summarize and analyze these data in standard format by routine techniques. This system and the techniques utilized are described in Appendix B.

In the initial setup of the National Interstate Surveillance Project, two stations were placed in the Kansas City area. When the Abatement Activity began its study, four stations were added to provide additional coverage. A more detailed description of these stations is presented in Appendix C.

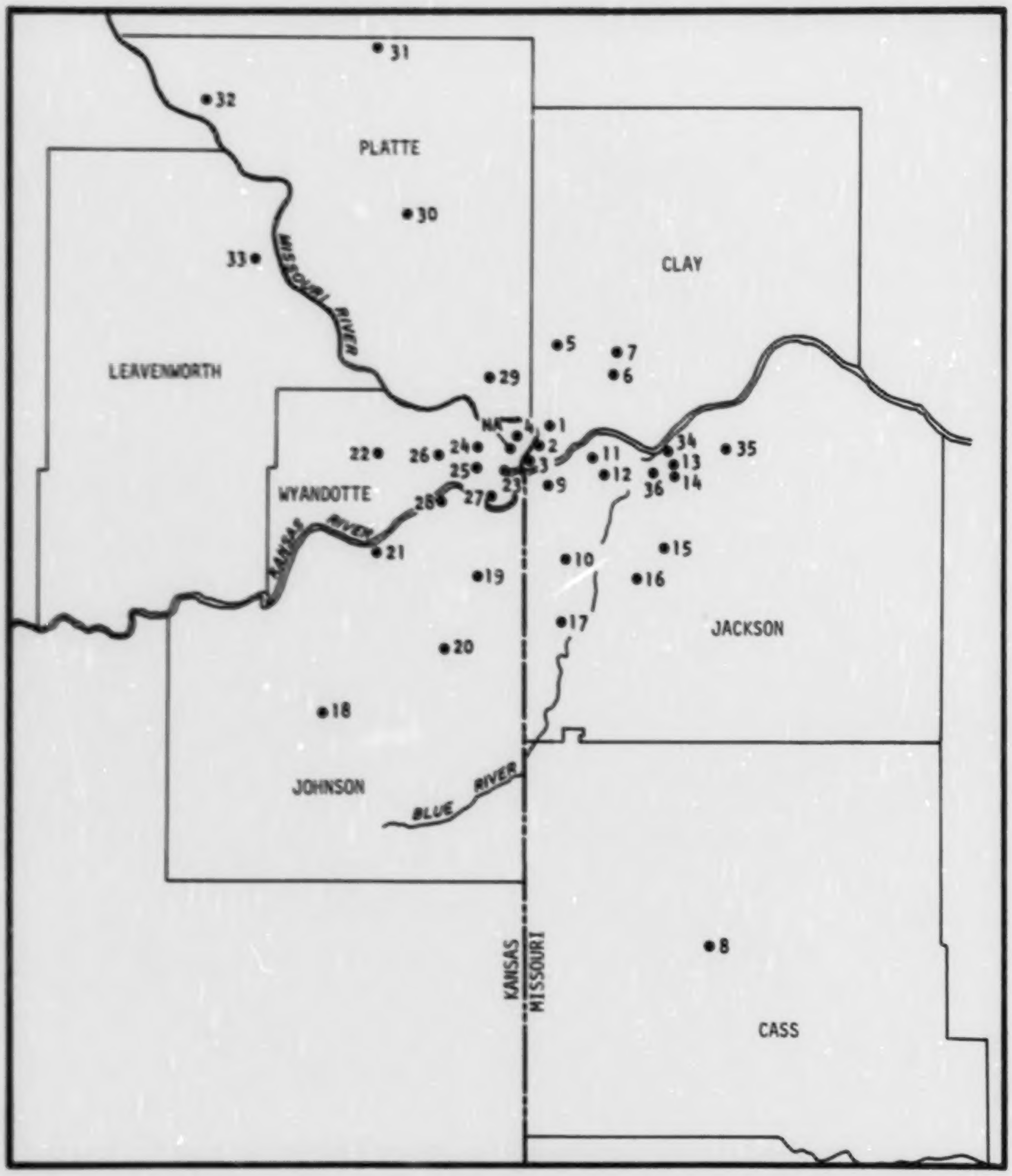

31
32
PLATTE
30
33
MISSOURI RIVER
CLAY
5
7
6
LEAVENWORTH
29
NK
4
1
2
3
22
26
24
25
23
9
11
12
34
13
36
14
35
WYANDOTTE
28
27
KANSAS RIVER
21
19
10
15
16
17
JACKSON
20
18
JOHNSON
BLUE RIVER
KANSAS
MISSOURI
8
CASS

Figure 6. Kansas City air quality monitoring network.

# II. RESULTS OF COMPREHENSIVE SURVEY

A comprehensive survey of air pollution in the Kansas City area was conducted during the period from October 1966 to October 1967. This survey, which included a measurement of air quality, air pollution emissions, meteorology, and effects of air pollutants, was conducted jointly by the Abatement Program, National Center for Air Pollution Control, and state and local air pollution control agencies. Most of the data presented in this report were generated in the course of this comprehensive survey. Available air-quality and meteorological data for other periods of time and from sources other than agencies participating directly in the comprehensive survey have been used to extend the survey data and to assist in their interpretation.

## PARTICULATE POLLUTANTS

### Suspended Particulate - High-Volume Sampler

Suspended particulates, as sampled by the high-volume sampler, were measured at 16 locations. Each sample was of 24 hours duration with a starting time at midnight. With the exception of the Price Farm station, which was in operation for only 5 months, all stations were in operation at least 7 months in the period from October 1966 to October 1967.

Frequency distributions of the daily measurements were computed for all concentration values obtained during the study period. A summary of these data appears in Table 2. Geometric mean concentration exceeded 75 micrograms per cubic meter ($\mu g/m^3$) at 9 of the 16 sampling sites. Highest arithmetic average concentrations were recorded at Morse School, 138 $\mu g/m^3$, and Fairfax, 131 $\mu g/m^3$; both locations had maximum 24-hour concentrations exceeding 300 $\mu g/m^3$. These stations recorded concentrations of 200 $\mu g/m^3$ or greater 10 percent of the days. Lowest averages were at the Price Farm, 59 $\mu g/m^3$, and Dorothy Moody School, 52 $\mu g/m^3$.

The percentages of days that certain specific concentrations were exceeded are indicated in Table 3. A level of 65 $\mu g/m^3$ was exceeded more than half the days at all but three sampling locations. Concentrations exceeding 200 $\mu g/m^3$ more than 1 percent of the days were found at seven locations.

Suspended particulate data are summarized on a seasonal basis in Table 4. Seasonal variations in arithmetic mean concentrations were not consistent from

Preceding page blank

BLANK PAGE

station to station; however, highest concentrations occurred most often in the spring and the fall. Concentrations exceeding 200 $\mu g/m^3$ occurred most frequently during the spring and fall at Morse School (with frequency almost as high during the spring at Municipal Airport South), during the summer at Fairfax, and during the winter and spring at East Kansas City, Kansas.

Quarterly composite suspended particulate samples obtained at the Waterworks, Police Garage, and Morse School stations were analyzed for metals, sulfates, benzene solubles, and benzo(a)pyrene content. These data appear in Table 5. Measurable quantities of copper, iron, lead, and manganese were found in all composite samples from all stations. Concentrations of antimony, beryllium, bismuth, cadmium, chromium, molybdenum and titanium were below the minimum detectable concentration in all quarterly composite samples analyzed.

Yearly average sulfate concentrations were approximately equal (6 to 7 $\mu g/m^3$) at the three sampling sites. Yearly average concentration of benzene-soluble materials was lowest at the Waterworks station (3.8 $\mu g/m^3$), and approximately equal at the Police Garage (6.2 $\mu g/m^3$) and Morse School stations (6.8 $\mu g/m^3$).

Yearly average concentration of benzo(a)pyrene was lower at the Waterworks station (0.70 $\mu g/1000\ m^3$) than at the Police Garage (1.44 $\mu g/1000\ m^3$) or at Morse School (1.50 $\mu g/1000\ m^3$). Quarterly samples ranged from 0.6 to 1.7 micrograms of benzo(a)pyrene per gram of total suspended particulate. The atmospheric concentration of benzo(a)pyrene was generally greater during the fall and winter months than during the spring and summer months.

Kansas City, Missouri, and Kansas City, Kansas, are included in the National Air Sampling Network (NASN). NASN is operated jointly by the National Center for Air Pollution Control of the Public Health Service and state and local air pollution control agencies. Suspended particulate samples are obtained with high-volume samplers on a biweekly basis. Data obtained for concentrations of total suspended particulates and for benzene-soluble materials for Kansas City, Kansas, and Kansas City, Missouri, are summarized in Tables 6 and 7.

Table 2. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY AVERAGE SUSPENDED PARTICULATE CONCENTRATION

| Station number | Station location | Operating period | No obs | Min value | Concentration, μg/$m^3$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Percent of days stated value exceeded: | | | | | | Max value | Arith mean | Geom mean |
| | | | | | 90 | 75 | 50 | 25 | 10 | 1 | | | |
| 1 | Waterworks | 10/66-10/67 | 171 | 18 | 38 | 57 | 80 | 103 | 135 | 220 | 269 | 85 | 77 |
| 3 | Municipal Airport South | 1/67-10/67 | 70 | 27 | 55 | 74 | 106 | 134 | 175 | 273* | 273 | 112 | 101 |
| 4 | Fairfax | 1/67-7/67 | 57 | 26 | 68 | 91 | 119 | 159 | 222 | 332* | 332 | 131 | 118 |
| 6 | Claycomo City Hall | 1/67-10/67 | 83 | 11 | 48 | 71 | 96 | 123 | 157 | 205 | 238 | 98 | 88 |
| 8 | Price Farm | 3/67-7/67 | 22 | 16 | 23 | 41 | 55 | 78 | 101 | 143* | 143 | 59 | 52 |
| 9 | Police Garage | 10/66-10/67 | 178 | 34 | 62 | 75 | 95 | 123 | 155 | 228 | 268 | 103 | 96 |
| 10 | UMKC Campus | 10/66-10/67 | 180 | 19 | 41 | 54 | 69 | 87 | 111 | 166 | 195 | 73 | 68 |
| 12 | Fire Station No. 21 | 1/67-10/67 | 62 | 34 | 59 | 74 | 85 | 111 | 162 | 195* | 195 | 96 | 90 |
| 14 | Independence Health Department | 1/67-10/67 | 120 | 18 | 45 | 63 | 77 | 96 | 114 | 141 | 181 | 80 | 72 |
| 20 | Dorothy Moody School | 1/67-10/67 | 71 | 13 | 26 | 34 | 48 | 66 | 82 | 110 | 113 | 52 | 47 |
| 23 | East KCK | 1/67-7/67 | 53 | 45 | 76 | 87 | 101 | 127 | 172 | 225* | 225 | 112 | 106 |
| 24 | Fire Station No. 14 | 1/67-7/67 | 55 | 27 | 58 | 68 | 86 | 101 | 125 | 163 | 169 | 88 | 83 |
| 27 | Morse School | 10/66-10/67 | 148 | 27 | 68 | 94 | 133 | 165 | 231 | 302 | 325 | 138 | 125 |
| 28 | Turner High School | 1/67-7/67 | 53 | 26 | 38 | 46 | 61 | 84 | 104 | 141* | 141 | 66 | 62 |
| 29 | Southeast Elementary | 1/67-7/67 | 50 | 18 | 28 | 46 | 66 | 84 | 110 | 133 | 202 | 70 | 61 |
| 33 | Leavenworth | 2/67-10/67 | 60 | 13 | 36 | 47 | 68 | 91 | 107 | 133* | 133 | 70 | 64 |

*Maximum value used.

Table 3. PERCENT OF TIME CONCENTRATIONS EXCEEDED SPECIFIC VALUES - SUSPENDED PARTICULATE BY HIGH-VOLUME SAMPLER

| Station number | Station location | Percent of days stated value exceeded: | | | | | |
|---|---|---|---|---|---|---|---|
| | | 65 µg/m$^3$ | 75 µg/m$^3$ | 100 µg/m$^3$ | 125 µg/m$^3$ | 150 µg/m$^3$ | 200 µg/m$^3$ |
| 1 | Waterworks | 65 | 56 | 27 | 15 | 7 | 2 |
| 3 | Municipal Airport South | 84 | 74 | 56 | 31 | 17 | 7 |
| 4 | Fairfax | 93 | 84 | 72 | 47 | 30 | 10 |
| 6 | Claycomo City Hall | 77 | 69 | 46 | 23 | 12 | 1 |
| 8 | Price Farm | 32 | 27 | 9 | 4 | 0 | 0 |
| 9 | Police Garage | 88 | 75 | 46 | 24 | 13 | 3 |
| 10 | UMKC Campus | 55 | 44 | 15 | 3 | 1 | 0 |
| 12 | Fire Station No. 21 | 84 | 74 | 34 | 18 | 10 | 0 |
| 14 | Independence Health Department | 72 | 52 | 19 | 4 | 2 | 0 |
| 20 | Dorothy Moody School | 25 | 13 | 4 | 0 | 0 | 0 |
| 23 | East KCK | 94 | 90 | 51 | 26 | 15 | 6 |
| 24 | Fire Station No. 14 | 84 | 60 | 25 | 7 | 4 | 0 |
| 27 | Morse School | 92 | 86 | 70 | 53 | 36 | 15 |
| 28 | Turner High School | 40 | 32 | 11 | 4 | 0 | 0 |
| 29 | Southeast Elementary | 52 | 30 | 18 | 6 | 4 | 2 |
| 33 | Leavenworth | 53 | 40 | 15 | 3 | 0 | 0 |

Table 4. SEASONAL SUSPENDED PARTICULATE CONCENTRATIONS

| Station number | Station location | Arithmetic mean, µg/m$^3$ | | | | | Percent of days value exceeded 200 µg/m$^3$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct-Nov[a] 1966 | Dec-Feb 1966-67 | Mar-May 1967 | June-Aug 1967 | Sept-Oct 1967 | Oct-Nov[a] 1966 | Dec-Feb 1966-67 | Mar-May 1967 | June-Aug 1967 | Sept-Oct 1967 |
| 1 | Waterworks | 114 | 80 | 84 | 83 | 76 | 10 | 0 | 0 | 0 | 0 |
| 3 | Municipal Airport South | | 116 | 120 | 108 | 98 | | 2 | 16 | 0 | 0 |
| 4 | Fairfax | | 139 | 133 | 121 | 131 | | 7 | 8 | 13 | 9 |
| 6 | Claycomo City Hall | | 108 | 100 | 94 | 91 | | 0 | 4 | 0 | 0 |
| 8 | Price Farm | | -[b] | 57 | 61 | - | | - | 0 | 0 | - |
| 9 | Police Garage | 105 | 107 | 109 | 91 | 100 | 0 | 4 | 2 | 2 | 8 |
| 10 | UMKC Campus | 77 | 73 | 77 | 62 | 82 | 0 | 0 | 0 | 0 | 0 |
| 12 | Fire Station No. 21 | | 92 | 106 | 89 | 73 | | 0 | 0 | 0 | 0 |
| 14 | Independence Health Department | | 70 | 90 | 78 | 77 | | 0 | 0 | 0 | 0 |
| 20 | Dorothy Moody School | | 43 | 59 | 51 | 39 | | 0 | 0 | 0 | 0 |
| 23 | East KCK | | 105 | 119 | 109 | - | | 8 | 8 | 0 | - |
| 24 | Fire Station No. 14 | | 80 | 91 | 87 | - | | 0 | 0 | 0 | - |
| 27 | Horse School | 164 | 121 | 151 | 123 | - | 35 | 3 | 20 | 8 | - |
| 28 | Turner High School | | 71 | 70 | 58 | - | | 0 | 0 | 0 | - |
| 29 | Southeast Elementary | | 57 | 81 | 56 | - | | 0 | 4 | 0 | - |
| 33 | Leavenworth | | 80 | 76 | 64 | 68 | | 0 | 0 | 0 | 0 |

[a] Only four stations in operation.

[b] Dash indicates insufficient data available.

Table 5. ANALYSES OF QUARTERLY AVERAGE SUSPENDED PARTICULATES - METALS, SULFATE, ORGANICS

| | Station 1: Waterworks | | | | | Station 9: Police Garage | | | | | Station 27: Morse School | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct-Dec | Jan-Mar | Apr-June | July-Sept | Average | Oct-Dec | Jan-Mar | Apr-June | July-Sept | Average | Oct-Dec | Jan-Mar | Apr-June | July-Sept | Average |
| Metals, µg/m³ | | | | | | | | | | | | | | | |
| Copper | 0.32 | 0.04 | 0.03 | 0.07 | 0.11 | 0.08 | 0.60 | 0.25 | 0.22 | 0.32 | 0.03 | 0.04 | 0.02 | 0.02 | 0.03 |
| Iron | 1.30 | 0.93 | 0.42 | 0.60 | 0.86 | 0.21 | 1.31 | 0.85 | 1.0 | 0.85 | 1.8 | 1.6 | 1.2 | 0.87 | 1.38 |
| Lead | 0.67 | 0.39 | 0.33 | 0.51 | 0.48 | 0.49 | 0.92 | 0.58 | 1.1 | 0.65 | 0.61 | 0.48 | 0.44 | 0.45 | 0.50 |
| Manganese | 0.030 | 0.024 | 0.016 | 0.022 | 0.025 | 0.013 | 0.038 | 0.043 | 0.045 | 0.035 | 0.062 | 0.040 | 0.037 | 0.031 | 0.044 |
| Nickel | 0.007 | -[a] | - | - | - | - | 0.068 | - | - | - | - | - | - | - | - |
| Tin | - | - | - | - | - | - | 0.02 | - | - | - | - | - | - | - | - |
| Titanium | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Vanadium | 0.004 | 0.004 | - | - | <0.004 | - | 0.01 | - | - | 0.006 | - | - | - | - | - |
| Zinc | 0.23 | - | - | - | <0.15 | - | - | - | - | - | - | - | - | - | - |
| Non-metals | 7.4 | 6.7 | 8.5 | 5.2 | 7.0 | 5.2 | 10.1 | 7.1 | 2.1 | 6.1 | 8.8 | 8.7 | 4.0 | 6.7 | 7.0 |
| Sulfates, µg/m³ | 7.3 | 8.0 | 11.2 | 6.4 | 8.2 | 5.5 | 8.1 | 7.5 | 2.1 | 5.8 | 5.7 | 4.7 | 3.0 | 4.1 | 4.4 |
| Sulfates, % | | | | | | | | | | | | | | | |
| Organics | | | | | | | | | | | | | | | |
| Benzene solubles, µg/m³ | 4.9 | 4.2 | 2.7 | 3.2 | 3.8 | 5.4 | 6.6 | 6.0 | 6.7 | 6.2 | 7.9 | 6.6 | 5.4 | 7.2 | 6.8 |
| Benzene solubles, % | 4.8 | 5.0 | 3.6 | 4.0 | 4.4 | 5.7 | 5.3 | 6.3 | 6.6 | 6.0 | 5.1 | 3.6 | 4.0 | 4.4 | 4.3 |
| Benzo (a) pyrene, µg/1000 m³ | 1.22 | 0.66 | 0.34 | 0.38 | 0.70 | 2.23 | 2.03 | 0.75 | 0.77 | 1.44 | 2.06 | 1.85 | 1.16 | 0.94 | 1.50 |
| Benzo (a) pyrene, µg/g | 1.5 | 1.3 | 0.6 | 0.6 | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.7 | 1.7 | 1.3 | 1.1 | 0.7 | 1.2 |

[a] Dash indicates concentration was below detectable limits. Lowest detectable concentrations are:

| | | | | | |
|---|---|---|---|---|---|
| Antimony | 0.040 µg/m³ | Chromium | 0.0064 µg/m³ | Tin | 0.001 µg/m³ |
| Beryllium | 0.0002 µg/m³ | Cobalt | 0.0064 µg/m³ | Titanium | 0.0096 µg/m³ |
| Bismuth | 0.0011 µg/m³ | Iron | 0.16 µg/m³ | Vanadium | 0.0032 µg/m³ |
| Cadmium | 0.011 µg/m³ | Molybdenum | 0.0024 µg/m³ | Zinc | 0.12 µg/m³ |
| | | Nickel | 0.0064 µg/m³ | | |

Table 6. SUMMARY OF NATIONAL AIR SAMPLING NETWORK DATA FOR SUSPENDED PARTICULATES IN KANSAS CITY, MISSOURI, AND KANSAS CITY, KANSAS

| Location | Year | No. samples | Annual concentration, $\mu g/m^3$ |  | % of time value exceeded: |  | Quarterly concentration, $\mu g/m^3$ |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Max value | Arith mean | 150 $\mu g/m^3$ | 200 $\mu g/m^3$ | Jan-Mar | Apr-June | July-Sept | Oct-Dec |
| Kansas City, Missouri | 1957 | 26 | 436 | 171 | 62 | 19 | 232 | 138 | 165 | 167 |
|  | 1958 | 24 | 345 | 193 | 63 | 42 | 242 | 180 | 209 | 157 |
|  | 1959 | 22 | 278 | 124 | 27 | 5 | 149 | 114 | 104 | 112 |
|  | 1960 | 26 | 343 | 142 | 19 | 8 | 177 | 135 | 122 | 133 |
|  | 1961 | 24 | 300 | 129 | 29 | 8 | 180 | 136 | 113 | 87 |
|  | 1962 | 24 | 227 | 140 | 38 | 13 | 184 | 114 | 122 | 133 |
|  | 1963 | 24 | 465 | 160 | 58 | 13 | 186 | 139 | 157 | 152 |
|  | 1964 | 25 | 310 | 137 | 28 | 12 | 160 | 123 | 114 | 150 |
|  | 1965 | 24 | 292 | 145 | 42 | 21 | 125 | 142 | 132 | 183 |
|  | 1966 | 24 | 156 | 116 | 13 | 0 | 118 | 124 | 113 | 110 |
|  | 1967 | 23 | 209 | 127 | 26 | 4 | 143 | 126 | 126 | 93 |
| Kansas City, Kansas | 1960 | 26 | 203 | 119 | 19 | 4 | 119 | 104 | 126 | 124 |
|  | 1962 | 24 | 391 | 163 | 46 | 21 | 129 | 151 | 209 | 169 |
|  | 1964 | 25 | 328 | 112 | 12 | 12 | 138 | 78 | 107 | 115 |
|  | 1966 | 23 | 148 | 90 | 0 | 0 | 85 | 87 | 97 | 87 |

Table 7. SUMMARY OF NATIONAL AIR SAMPLING NETWORK DATA FOR BENZENE-SOLUBLE PARTICULATES IN KANSAS CITY, MISSOURI, AND KANSAS CITY, KANSAS

| Location | Year | No. samples | Annual concentration, µg/m$^3$ | | Quarterly concentration, µg/m$^3$ | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Max value | Arith mean | % of suspended particulate | Jan-Mar | Apr-June | July-Sept | Oct-Dec |
| Kansas City, Missouri | 1957 | 26 | 30.1 | 9.6 | 5.5 | 13.3 | 6.4 | 7.8 | 11.3 |
| | 1958 | 24 | 37.4 | 15.9 | 8.2 | 15.1 | 15.6 | 18.9 | 13.8 |
| | 1959 | 22 | 26.4 | 9.6 | 7.8 | 12.1 | 7.7 | 8.7 | 10.9 |
| | 1960 | 26 | 18.0 | 10.9 | 7.1 | 12.6 | 8.9 | 8.2 | 11.2 |
| | 1961 | 24 | 31.9 | 9.6 | 7.5 | 15.3 | 10.7 | 7.4 | 5.1 |
| | 1962 | 24 | 24.2 | 9.3 | 6.6 | 12.0 | 6.0 | 7.8 | 11.2 |
| | 1963 | 24 | 28.8 | 9.7 | 6.1 | 9.8 | 8.4 | 11.0 | 9.5 |
| | 1964 | 25 | nd[a] | 7.6 | 5.6 | 11.1 | 5.1 | 6.2 | 7.3 |
| | 1965 | 24 | nd[a] | 9.4 | 6.5 | 6.0 | 5.7 | 7.0 | 18.8 |
| Kansas City, Kansas | 1960 | 26 | 21.3 | 9.0 | 7.6 | 7.9 | 7.2 | 9.9 | 10.8 |
| | 1962 | 24 | 31.7 | 10.7 | 6.6 | 7.7 | 11.3 | 13.7 | 10.8 |
| | 1964 | 25 | nd[a] | 7.2 | 6.4 | 11.3 | 2.7 | 7.0 | 6.6 |

[a] nd - not determined, but quarterly composited samples were analyzed.

Annual arithmetic mean concentrations of total suspended particulates in Kansas City, Missouri, from 1957 to 1967 aresshown in Figure 7. Concentrations measured in 1957 and 1958 were significantly greater than those measured from 1959 to 1967. Since 1958, there has been no significant annual trend in suspended particulate concentrations.

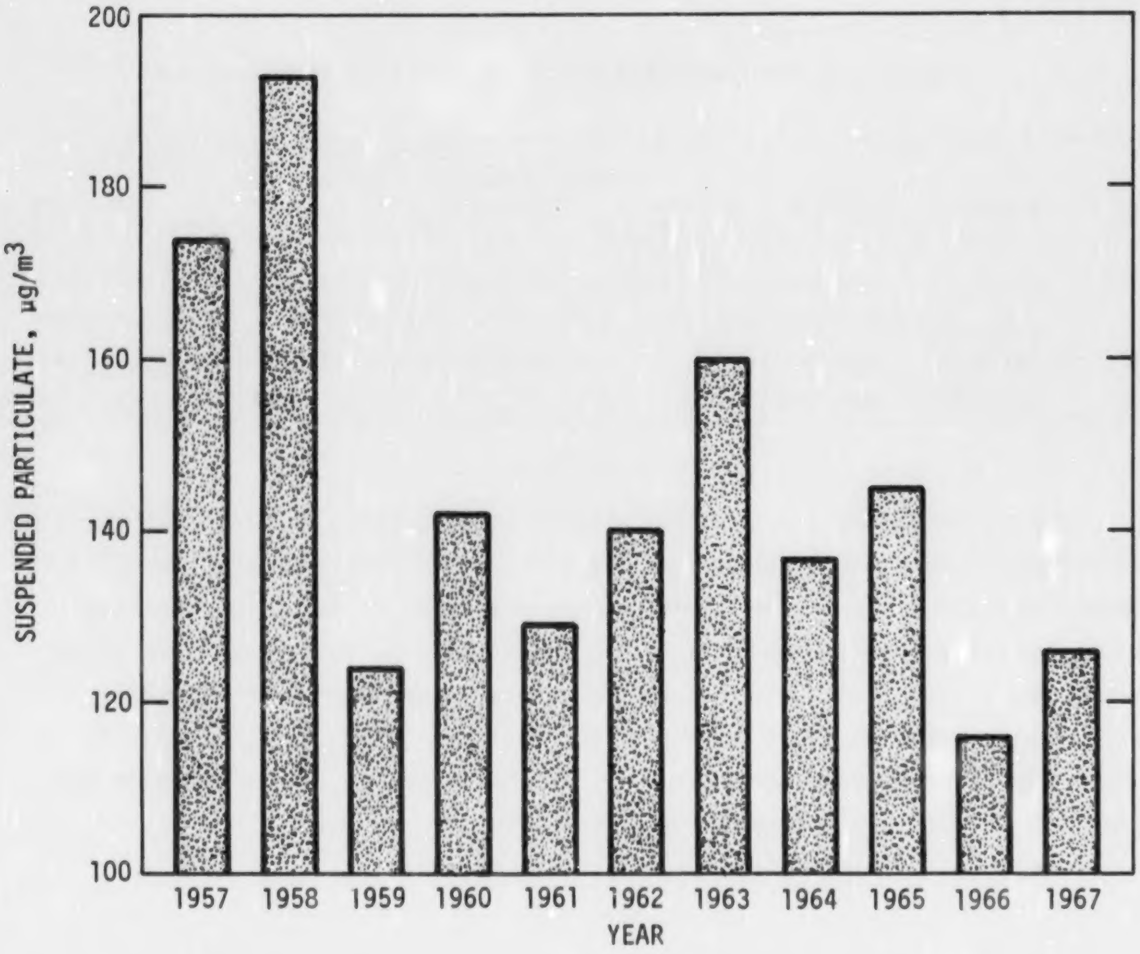


Figure 7. Annual variation in suspended particulate concentrations - NASN data, Kansas City, Missouri.

## Suspended Particulate - Soiling Index

Soiling index was measured from October 1966 to October 1967 at four stations using AISI sequential filter paper tape samplers. Data obtained over 2-hour averaging times are reported in Cohs per 1000 lineal feet and are summarized in Table 8. Maximum values ranged from 2.7 at Waterworks to 5.2 at the University of Missouri Kansas City Campus. Geometric means for the entire period of observation varied from 0.2 to 0.4 Cohs/1000 lineal feet.

Table 8. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF 2-HOUR SOILING INDEX VALUES

| Station number | Station location | Operating period | No. obs | Soiling index, Cohs/1000 lineal feet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min value | Percent of time stated value exceeded: | | | | | | | Max value | Arith mean | Geom mean | Std dev |
| | | | | | 90 | 70 | 50 | 30 | 16 | 10 | 1 | | | | |
| 1 | Waterworks | 10/66-10/67 | 3963 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.5 | 0.7 | 1.5 | 2.7 | 0.3 | 0.2 | 0.3 |
| 9 | Police Garage | 10/66-10/67 | 4023 | 0.1 | 0.1 | 0.1 | 0.3 | 0.5 | 0.7 | 0.9 | 1.9 | 4.7 | 0.4 | 0.3 | 0.4 |
| 10 | UMKC Campus | 10/66-10/67 | 4068 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 1.4 | 5.2 | 0.3 | 0.2 | 0.3 |
| 27 | Morse School | 10/66-10/67 | 3113 | 0.1 | 0.1 | 0.2 | 0.4 | 0.7 | 1.1 | 1.4 | 2.6 | 4.3 | 0.6 | 0.4 | 0.5 |

Values exceeding 1.9 Cohs/1000 lineal feet occurred 4 percent of the time at the Morse School and 1 percent of the time at the Police Garage (Table 9). Seasonal variations in soiling index values are shown in Table 10. Seasonal median concentrations varied from 0.1 to 0.4 at all stations except the Morse School, where values of 0.7 and 0.6 were obtained for the summer and fall, respectively. Values exceeding 0.9 Cohs/1000 lineal feet occurred most frequently during the winter at all stations except the Morse School, where these concentrations occurred most frequently during the summer and fall.

Table 9. PERCENT OF TIME SELECTED 2-HOUR AVERAGE SOILING INDEX VALUES WERE EXCEEDED OCTOBER 1966 - OCTOBER 1967

| Station number | Station location | Percent of time exceeding given value in Cohs/1000 lineal feet: | | | | |
|---|---|---|---|---|---|---|
| | | 0.4 | 0.9 | 1.4 | 1.9 | 2.4 |
| 1 | Waterworks | 25 | 5 | 1 | <1 | <1 |
| 9 | Police Garage | 34 | 9 | 3 | 1 | <1 |
| 10 | UMKC Campus | 20 | 3 | 1 | <1 | <1 |
| 27 | Morse School | 54 | 20 | 9 | 4 | 1 |

Table 10. SEASONAL VARIATION IN SOILING INDEX

| Station number | Station location | Arithmetic mean, Cohs/1000 lineal feet | | | |
|---|---|---|---|---|---|
| | | Oct'66-Nov'66<br>Sept'67-Oct'67 | Dec'66-<br>Feb'67 | Mar'67-<br>May'67 | June'67<br>Aug '67 |
| 1 | Waterworks | 0.3 | 0.4 | 0.4 | 0.3 |
| 9 | Police Garage | 0.4 | 0.6 | 0.4 | 0.3 |
| 10 | UMKC Campus | 0.3 | 0.3 | 0.3 | 0.2 |
| 27 | Morse School | 0.7 | 0.5 | 0.6 | 0.9 |
| | | Median, Cohs/1000 lineal feet | | | |
| 1 | Waterworks | 0.1 | 0.2 | 0.2 | 0.2 |
| 9 | Police Garage | 0.3 | 0.4 | 0.3 | 0.2 |
| 10 | UMKC Campus | 0.2 | 0.2 | 0.2 | 0.1 |
| 27 | Morse School | 0.6 | 0.3 | 0.4 | 0.7 |
| | | % of time 2-hr concentrations exceeded 0.9 Cohs/1000 lineal feet | | | |
| 1 | Waterworks | 4 | 8 | 4 | 3 |
| 9 | Police Garage | 10 | 19 | 5 | 3 |
| 10 | UMKC Campus | 4 | 6 | 3 | 1 |
| 27 | Morse School | 24 | 12 | 19 | 32 |

## Settleable Particulate - Dustfall

Settleable particulate were collected over monthly intervals for varying periods from January 1967 to October 1967 at 35 sampling sites using dustfall receptacles. Data obtained are reported in tons per square mile per month (tons/mi$^2$-mo) and are summarized in Table 11. The highest arithmetic and geometric means of 12 tons/mi$^2$-mo were measured at West Independence. The maximum monthly dustfall was 22 tons/mi$^2$-mo. Dustfall values in excess of 15 tons/mi$^2$-mo were measured at 5 sampling stations; values in excess of 20 tons per square mile per month were obtained at Price Farm and at Hickory Grove School.

Table 11. SETTLEABLE PARTICULATE - DUSTFALL

| Station number | Station location | Operating period | No. obs. | Dustfall, tons/mi$^2$-mo Min | Max | Arith mean | Geom mean | Std dev |
|---|---|---|---|---|---|---|---|---|
| 1 | Waterworks | 1/67- 9/67 | 8 | 3 | 10 | 5 | 5 | 2 |
| 3 | Municipal Airport South | 1/67- 9/67 | 9 | 3 | 10 | 5 | 5 | 2 |
| 4 | Fairfax | 1/67- 9/67 | 9 | 3 | 13 | 7 | 6 | 3 |
| 5 | Gladstone Water Department | 2/67-10/67 | 6 | 5 | 18 | 9 | 9 | 5 |
| 6 | Claycomo City Hall | 1/67-10/67 | 9 | 4 | 7 | 6 | 5 | 1 |
| 7 | Pleasant Valley City Hall | 2/67- 7/67 | 5 | 3 | 6 | 4 | 4 | 1 |
| 8 | Price Farm | 3/67-10/67 | 8 | 1 | 21 | 7 | 5 | 6 |
| 9 | Police Garage | 1/67- 8/67 | 7 | 4 | 15 | 7 | 7 | 4 |
| 10 | UMKC Campus | 1/67- 8/67 | 7 | 2 | 8 | 4 | 4 | 2 |
| 11 | Pleasant Valley School | 2/67-10/67 | 9 | 4 | 11 | 8 | 8 | 2 |
| 12 | Fire Station No. 21 | 2/67-10/67 | 8 | 5 | 9 | 7 | 6 | 2 |
| 13 | Central Independence | 2/67-10/67 | 8 | 3 | 10 | 5 | 5 | 3 |
| 14 | Independence Health Department | 1/67- 8/67 | 7 | 2 | 10 | 6 | 5 | 3 |
| 15 | South Independence | 2/67-10/67 | 8 | 2 | 6 | 4 | 5 | 1 |
| 16 | Raytown City Hall | 2/67-10/67 | 8 | 1 | 14 | 5 | 4 | 4 |
| 17 | John Hartman School | 2/67-10/67 | 8 | <1 | 7 | 3 | 4 | 2 |
| 18 | Olathe Substation | 2/67-10/67 | 9 | 1 | 6 | 3 | 2 | 1 |
| 19 | Hickory Grove School | 1/67- 8/67 | 5 | 3 | 22 | 7 | 3 | 8 |
| 20 | Dorothy Moody School | 1/67- 8/67 | 7 | 1 | 6 | 3 | 5 | 2 |
| 21 | North Johnson County | 2/67-10/67 | 8 | 1 | 5 | 3 | 3 | 1 |
| 22 | Bethel Fire Station | 3/67-10/67 | 7 | 4 | 7 | 5 | 3 | 1 |
| 23 | East KCK | 1/67- 7/67 | 6 | 3 | 10 | 6 | 5 | 3 |
| 24 | Fire Station No. 14 | 1/67-10/67 | 10 | 1 | 7 | 4 | 4 | 2 |
| 25 | Mark Twain School | 2/67-10/67 | 8 | 3 | 11 | 6 | 5 | 3 |
| 26 | Wyandotte Swim Club | 3/67-10/67 | 8 | 2 | 5 | 3 | 3 | 1 |
| 27 | Morse School | 1/67- 8/67 | 6 | 4 | 9 | 6 | 6 | 2 |
| 28 | Turner High School | 2/67-10/67 | 9 | 2 | 11 | 5 | 4 | 3 |
| 29 | Southeast Elementary | 2/67-10/67 | 9 | 2 | 9 | 4 | 4 | 2 |
| 30 | Kerrville Water Station No. 4 | 1/67-10/67 | 9 | 1 | 4 | 2 | 2 | 1 |
| 31 | Dearborn City Limits | 2/67- 9/67 | 7 | 2 | 11 | 5 | 4 | 3 |
| 32 | West Platte County | 2/67- 9/67 | 5 | 2 | 6 | 4 | 4 | 2 |
| 33 | Leavenworth | 3/67- 9/67 | 6 | 2 | 14 | 6 | 5 | 4 |
| 34 | Sewage Treatment Plant | 3/67- 9/67 | 6 | 2 | 8 | 4 | 4 | 2 |
| 35 | East Independence | 3/67-10/67 | 7 | 2 | 10 | 5 | 4 | 2 |
| 36 | West Independence | 3/67- 9/67 | 6 | 9 | 19 | 12 | 12 | 4 |

## GASEOUS POLLUTANTS

### Sulfur Dioxide

Two-hour average atmospheric sulfur dioxide concentrations were measured at four stations using automatic sequential samplers and the p-rosaniline spectrophotometric method of detection. Data obtained are summarized in Table 12. Arithmetic and geometric mean concentrations were 0.01 part per million (ppm) at all stations. Maximum concentrations varied from 0.11 ppm at the University of Missouri Kansas City Campus to 0.20 ppm at the Police Garage. Concentrations exceeding 0.15 ppm, 2-hour average, occurred for less than 1 percent of the time at all stations.

Cumulative percent frequency of occurrence of 24-hour average $SO_2$ concentration is indicated in Table 13. Maximum concentrations ranged from 0.02 ppm at the University of Missouri Kansas City Campus to 0.08 ppm at the Police Garage. Twenty-four hour concentrations exceeded 0.05 ppm 1 percent of the time at the Police Garage.

Seasonal variation in sulfur dioxide concentrations is indicated in Table 14. Sulfur dioxide concentration is highest during the winter at the Waterworks and Police Garage stations. There was no seasonal difference in arithmetic or geometric mean concentrations at the University of Missouri Kansas City Campus or the Morse School for the three seasons that measurements were available; however, the upper percentile concentration was higher during the winter months.

Table 12. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF 2-HOUR SULFUR DIOXIDE CONCENTRATION

| Station number | Station location | Operating period | No. obs. | Concentration, ppm | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min value | Percent of time stated value exceeded: | | | | | | | Max value | Arith. mean | Geom mean | Std dev |
| | | | | | 90 | 70 | 50 | 30 | 16 | 10 | 1 | | | | |
| 1 | Waterworks | 12/66-10/67 | 1818 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.09 | 0.14 | 0.01 | 0.01 | 0.02 |
| 9 | Police Garage | 12/66-10/67 | 1819 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 | 0.10 | 0.20 | 0.01 | 0.01 | 0.02 |
| 10 | UMKC Campus | 12/66- 7/67 | 1368 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 | 0.11 | 0.01 | 0.01 | 0.01 |
| 27 | Morse School | 12/66- 7/67 | 1438 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.06 | 0.15 | 0.01 | 0.01 | 0.01 |

Table 13. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY AVERAGE SULFUR DIOXIDE CONCENTRATION VARYING PERIODS - 1966-67

| Station number | Station location | No. obs | Concentration, ppm | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min value | Percent of time stated value exceeded: | | | | | | Max value | Arith mean | Geom mean |
| | | | | 90 | 75 | 50 | 25 | 10 | 1 | | | |
| 1 | Waterworks | 159 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.02 | 0.04 | 0.05 | 0.01 | 0.01 |
| 9 | Police Garage | 160 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | 0.03 | 0.05 | 0.08 | 0.01 | 0.01 |
| 10 | UMKC Campus | 120 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | <0.01 |
| 27 | Morse School | 120 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.02 | 0.04 | 0.04 | 0.01 | <0.01 |

Table 14. SEASONAL VARIATION IN SULFUR DIOXIDE CONCENTRATION
2-hour samples

| Station number | Station location | Arithmetic mean | | | |
|---|---|---|---|---|---|
| | | Dec'66-Feb'67 | Mar'67-May'67 | June'67-Aug'67 | Sept'67-Oct'67 |
| 1 | Waterworks | 0.02 | 0.01 | 0.01 | 0.01 |
| 9 | Police Garage | 0.03 | 0.01 | 0.01 | 0.01 |
| 10 | UMKC Campus | 0.01 | 0.01 | 0.01 | nd[a] |
| 27 | Morse School | 0.01 | 0.01 | 0.01 | nd |
| | | Geometric mean | | | |
| 1 | Waterworks | 0.01 | 0.01 | 0.01 | 0.01 |
| 9 | Police Garage | 0.02 | 0.01 | 0.01 | 0.01 |
| 10 | UMKC Campus | 0.01 | 0.01 | 0.01 | nd |
| 27 | Morse School | 0.01 | 0.01 | 0.01 | nd |
| | | 2-hour concentrations exceeded 1% of time | | | |
| 1 | Waterworks | 0.11 | 0.07 | 0.05 | 0.07 |
| 9 | Police Garage | 0.15 | 0.05 | 0.05 | 0.07 |
| 10 | UMKC Campus | 0.04 | 0.03 | 0.02 | nd |
| 27 | Morse School | 0.10 | 0.04 | 0.02 | nd |

[a] nd - not determined

## Sulfation

Monthly average sulfation rates of lead peroxide candles were determined at 35 sampling stations for varying periods from January 1967 to October 1967. Data obtained are reported in milligrams of sulfur trioxide per 100 square centimeters per day (mg $SO_3$/100 cm$^2$-day) and are summarized in Table 15.

Sulfation rate, a measure of sulfur dioxide dosage, is used to estimate the monthly average sulfur dioxide concentration. Highest average sulfation rate (0.6 mg $SO_3$/100 cm$^2$-day) was recorded at Municipal Airport South and Fairfax. Mean sulfation rates were 0.3 mg $SO_3$/100 cm$^2$-day or greater at 9 of the 35 sampling stations. Maximum monthly sulfation rates exceeding 0.5 mg $SO_3$/100 cm$^2$-day were measured at 10 stations (Table 16). Sulfation rates exceeding 1.0 were observed at Leavenworth and at the Sewage Treatment Plant.

Table 15. MONTHLY SULFATION DATA

| Station number | Station location | Operating period | No. obs | Concentration, mg $SO_3$/100 $cm^2$-day Min | Max | Arith mean |
|---|---|---|---|---|---|---|
| 1 | Waterworks | 1/67-10/67 | 10 | 0.1 | 0.6 | 0.3 |
| 3 | Municipal Airport South | 1/67-10/67 | 10 | 0.1 | 1.0 | 0.6 |
| 4 | Fairfax | 1/67-10/67 | 10 | 0.1 | 0.8 | 0.6 |
| 5 | Gladstone Water Department | 3/67-10/67 | 6 | 0.1 | 0.5 | 0.2 |
| 6 | Claycomo City Hall | 1/67-10/67 | 9 | 0.1 | 0.4 | 0.1 |
| 7 | Pleasant Valley City Hall | 2/67- 6/67 | 5 | 0.1 | 0.4 | 0.3 |
| 8 | Price Farm | 3/67-10/67 | 8 | 0.1 | 0.1 | 0.1 |
| 9 | Police Garage | 1/67- 9/67 | 9 | 0.1 | 0.9 | 0.4 |
| 10 | UMKC Campus | 1/67- 9/67 | 8 | 0.1 | 0.4 | 0.2 |
| 11 | Pleasant Valley School | 2/67-10/67 | 9 | 0.1 | 0.5 | 0.3 |
| 12 | Fire Station No. 21 | 2/67-10/67 | 9 | 0.1 | 0.5 | 0.2 |
| 13 | Central Independence | 2/67-10/67 | 8 | 0.1 | 0.3 | 0.2 |
| 14 | Independence Health Department | 1/67- 9/67 | 9 | 0.1 | 0.6 | 0.3 |
| 15 | South Independence | 2/67-10/67 | 9 | 0.1 | 0.4 | 0.1 |
| 16 | Raytown City Hall | 2/67-10/67 | 8 | 0.1 | 0.4 | 0.1 |
| 17 | John Hartman School | 2/67- 8/67 | 6 | 0.1 | 0.3 | 0.1 |
| 18 | Olathe Substation | 2/67-10/67 | 9 | 0.1 | 0.2 | 0.1 |
| 19 | Hickory Grove School | 1/67- 8/67 | 8 | 0.1 | 0.3 | 0.1 |
| 20 | Dorothy Moody School | 1/67- 9/67 | 9 | 0.1 | 0.2 | 0.1 |
| 21 | North Johnson County | 2/67- 9/67 | 8 | 0.1 | 0.2 | 0.1 |
| 22 | Bethel Fire Station | 2/67-10/67 | 8 | 0.1 | 0.4 | 0.1 |
| 23 | East KCK | 1/67- 7/67 | 7 | 0.1 | 0.7 | 0.3 |
| 24 | Fire Station | 1/67-10/67 | 10 | 0.1 | 0.6 | 0.2 |
| 25 | Mark Twain School | 2/67-10/67 | 8 | 0.1 | 0.4 | 0.2 |
| 26 | Wyandotte Swim Club | 2/67-10/67 | 9 | 0.1 | 0.3 | 0.1 |
| 27 | Morse School | 1/67- 9/67 | 8 | 0.1 | 0.6 | 0.2 |
| 28 | Turner High School | 2/67-10/67 | 9 | 0.1 | 0.3 | 0.1 |
| 29 | Southeast Elementary | 2/67-10/67 | 9 | 0.1 | 0.4 | 0.2 |
| 30 | Kerrville Water Station No. 4 | 1/67-10/67 | 10 | 0.1 | 0.2 | 0.1 |
| 31 | Dearborn City Limits | 2/67-10/67 | 9 | 0.1 | 0.2 | 0.1 |
| 32 | West Platte County | 2/67-10/67 | 9 | 0.1 | 0.2 | 0.1 |
| 33 | Leavenworth | 3/67-10/67 | 7 | 0.1 | 1.6 | 0.2 |
| 34 | Sewage Treatment Plant | 3/67-10/67 | 8 | 0.1 | 1.1 | 0.5 |
| 35 | East Independence | 3/67-10/67 | 8 | 0.1 | 0.3 | 0.2 |
| 36 | West Independence | 3/67-10/67 | 8 | 0.1 | 0.3 | 0.1 |

Table 16. NUMBER OF MONTHS SULFATION VALUES CONCENTRATIONS EXCEEDED SPECIFIC VALUES

| Station number | Station location | No. obs | Sulfation, mg $SO_3$/100 $cm^2$-day | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0.25 | 0.50 | 0.75 | 1.0 | 2.0 |
| 1 | Waterworks | 10 | 8 | 1 | 0 | 0 | 0 |
| 3 | Municipal Airport South | 10 | 9 | 6 | 2 | 0 | 0 |
| 4 | Fairfax | 10 | 9 | 5 | 3 | 0 | 0 |
| 5 | Gladstone Water Department | 6 | 2 | 0 | 0 | 0 | 0 |
| 6 | Claycomo City Hall | 9 | 2 | 0 | 0 | 0 | 0 |
| 7 | Pleasant Valley City Hall | 5 | 2 | 0 | 0 | 0 | 0 |
| 8 | Price Farm | 8 | 0 | 0 | 0 | 0 | 0 |
| 9 | Police Garage | 9 | 6 | 2 | 2 | 0 | 0 |
| 10 | UMKC Campus | 8 | 3 | 0 | 0 | 0 | 0 |
| 11 | Pleasant Valley School | 9 | 5 | 0 | 0 | 0 | 0 |
| 12 | Fire Station No. 21 | 9 | 3 | 0 | 0 | 0 | 0 |
| 13 | Central Independence | 8 | 1 | 0 | 0 | 0 | 0 |
| 14 | Independence Health Department | 9 | 4 | 2 | 0 | 0 | 0 |
| 15 | South Independence | 9 | 1 | 0 | 0 | 0 | 0 |
| 16 | Raytown City Hall | 8 | 1 | 0 | 0 | 0 | 0 |
| 17 | John Hartman School | 6 | 1 | 0 | 0 | 0 | 0 |
| 18 | Olathe Substation | 9 | 0 | 0 | 0 | 0 | 0 |
| 19 | Hickory Grove School | 8 | 1 | 0 | 0 | 0 | 0 |
| 20 | Dorothy Moody School | 9 | 0 | 0 | 0 | 0 | 0 |
| 21 | North Johnson County | 8 | 0 | 0 | 0 | 0 | 0 |
| 22 | Bethel Fire Station | 8 | 1 | 0 | 0 | 0 | 0 |
| 23 | East KCK | 7 | 3 | 1 | 0 | 0 | 0 |
| 24 | Fire Station No. 14 | 10 | 5 | 1 | 0 | 0 | 0 |
| 25 | Mark Twain School | 8 | 3 | 0 | 0 | 0 | 0 |
| 26 | Wyandotte Swim Club | 9 | 3 | 0 | 0 | 0 | 0 |
| 27 | Morse School | 8 | 3 | 1 | 0 | 0 | 0 |
| 28 | Turner High School | 9 | 1 | 0 | 0 | 0 | 0 |
| 29 | Southeast Elementary | 9 | 4 | 0 | 0 | 0 | 0 |
| 30 | Kerrville Water Station No. 4 | 10 | 0 | 0 | 0 | 0 | 0 |
| 31 | Dearborn City Limits | 9 | 0 | 0 | 0 | 0 | 0 |
| 32 | West Platte County | 9 | 0 | 0 | 0 | 0 | 0 |
| 33 | Leavenworth | 7 | 1 | 1 | 1 | 1 | 0 |
| 34 | Sewage Treatment Plant | 8 | 6 | 4 | 1 | 1 | 0 |
| 35 | East Independence | 8 | 1 | 0 | 0 | 0 | 0 |
| 36 | West Independence | 8 | 1 | 0 | 0 | 0 | 0 |

The average sulfation rate for all stations was used to indicate monthly variation in sulfation (Figure 8). Sulfation rates were highest in January and February decreased progressively to May, and then increased progressively from July to October. January and February values were about 3.5 times greater than June and July values.

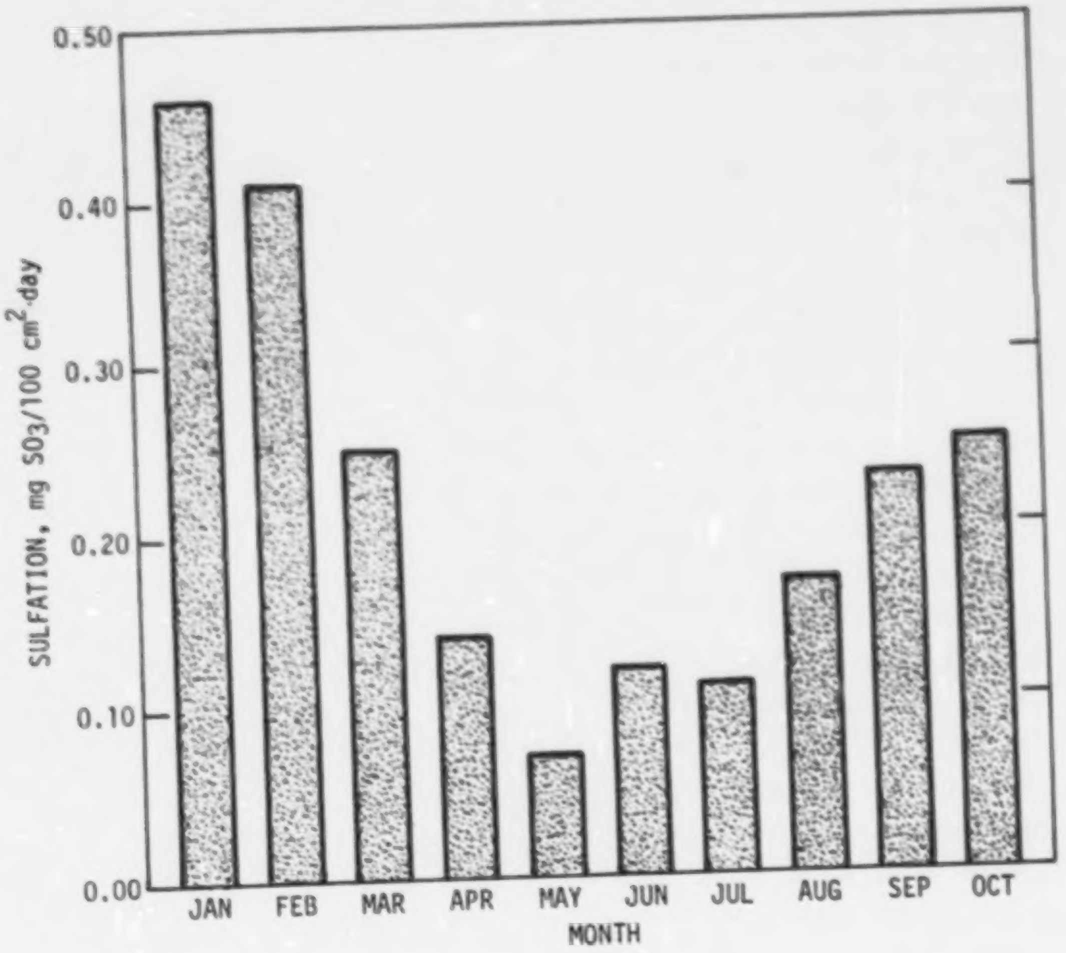


Figure 8. Monthly average sulfation rate for all stations.

## AIR POLLUTION EFFECTS

Information concerning the effects of air pollution on vegetation and materials was gathered in the survey area. Both indigenous vegetation and vegetation grown experimentally at three locations were examined for damage. Effects such as soiling, corrosion, and deterioration of materials were also investigated.

### Vegetation Effects

During the 1967 growing season, a botanist made three series of inspections of indigenous vegetation in the Kansas City area. These inspection tours consisted of observing vegetation at 15 to 20 locations. The findings of these inspections are reported in Table 17. Severe damage means that 50 to 100 percent of the leaf tissue is damaged; extensive means that 25 to 50 percent is damaged; and moderate means that 5 to 25 percent is damaged.

Experimental vegetation was cultured hydroponically in vermiculite in exposure chambers from July 17 through September 5, 1967, at the Waterworks and Police Garage, Kansas City, Missouri, and at Morse School, Kansas City, Kansas. In addition, a control chamber ventilated with clean air was operated at the Waterworks. The exposure chambers were ventilated with ambient air at a rate of about one air change per minute. The control chamber was ventilated with filtered air, which was passed through activated charcoal. Tobacco W3, pinto bean, geranium, petunia, begonia, and corn plants were exposed in each chamber. The pots were kept in shallow trays with Hoagland nutrient solution; distilled water was added as needed. Each week, the vermiculite was flushed with distilled water and the plants were placed in fresh nutrient solution. Exposures were arranged so that damage could be determined during the entire exposure period and during each of the 3-week increments of the exposure period. Vegetation was also examined for short-term damage each week when the plants were tended.

Table 18 summarizes the leaf damage found on the experimental vegetation. The time of occurrence of the damage is designated as period 1 or 2, which corresponds to the time intervals from July 17 to August 10 and August 11 to September 5, 1967. In Table 18 both the type and amount of damage are listed. When the type of injury is specific to a certain pollutant, it is listed according to pollutant; however, if the type is nonspecific, it is listed according to type of damage, such as chlorosis.

Table 17. INJURY FOUND ON INDIGENOUS VEGETATION GROWN AT VARIOUS LOCATIONS IN KANSAS CITY AREA - 1967

| Date | | Plant variety | Pollutant cause | Degree of damage |
|---|---|---|---|---|
| 5/15 | Stephenson's orchard 1/2 mile south of Sibley power plant | Peach trees<br>Rose bush<br>Dogwood<br>Red delicious apple<br>Clover<br>Spirea<br>Strawberry | $SO_2$<br>$SO_2$<br>$SO_2$<br>$SO_2$<br>$SO_2$<br>$SO_2$<br>$SO_2$ | Severe<br>Severe<br>Severe<br>Severe<br>Severe<br>Severe<br>Severe |
| 5/15 | Across street from Sibley Elementary School about 1 mile from Sibley power plant | Tomato<br>Peony<br>Petunia<br>Sweet peas<br>Hybiscus | $SO_2$<br>$SO_2$<br>$SO_2$<br>$SO_2$<br>$SO_2$ | Extensive<br>Extensive<br>Extensive<br>Extensive<br>Extensive |
| 5/15 | 2 miles northwest of Sibley power plant | Tomato<br>Petunia | $SO_2$<br>$SO_2$ | Moderate<br>Moderate |
| 5/15 | 3 miles west of Sibley power plant | Tomato | $SO_2$ | Moderate |
| 5/15 | Near Truman Library, Highway 24 Independence, Missouri | Hedge<br>Maple<br>Crab apple<br>Pine needle<br>Oak | Acid mist or fly ash<br>Acid mist or fly ash<br>Acid mist or fly ash<br>Acid mist or fly ash<br>Acid mist or fly ash | Extensive<br>Extensive<br>Extensive<br>Extensive<br>Extensive |
| 5/15 | Sugar Creek North River and Brewster land section, Independence, Missouri | Sweet peas<br>Grape vine<br>Apple<br>Tulip trees | Acid mist or fly ash<br>Acid mist or fly ash<br>Acid mist or fly ash<br>Acid mist or fly ash | Extensive<br>Extensive<br>Extensive<br>Extensive |
| 5/15 | 3118 North River Road northeast of Sugar Creek Refinery | Tomato<br>Alfalfa<br>Rasberry<br>Strawberry | Acid mist or fly ash<br>Acid mist or fly ash<br>Acid mist or fly ash<br>Acid mist or fly ash | Extensive<br>Extensive<br>Extensive<br>Extensive |
| 7/18 | Fairfax Airport, Kansas City | Red bud | Acid mist | Moderate |
| 7/18 | Fairfax Drainage Dist. 1620 Fairfax Ave. | Petunia<br>Verbenia | $SO_2$<br>$SO_2$ | Extensive<br>Extensive |
| 7/18 | In front of courthouse, downtown Kansas City, Missouri | Petunia | Oxidant | Extensive |
| 7/19 | Stephenson's orchard 1/2 mile south of Sibley power plant | Maple<br>Ragweed<br>Spirea | $SO_2$<br>$SO_2$<br>$SO_2$ | Moderate<br>Extensive<br>Moderate |
| 7/19 | Shropshire residence near Sibley Elementary School 1 mile from Sibley power plant | Apple<br>Spirea<br>Sweet peas | $SO_2$<br>$SO_2$<br>$SO_2$ | Extensive<br>Extensive<br>Extensive |
| 7/19 | Near Osage Honey Store 2 miles northeast of power plant | Grass<br>Clover<br>Sugar maple<br>Silver maple | $SO_2$<br>$SO_2$<br>$SO_2$<br>$SO_2$ | Extensive<br>Moderate<br>Moderate<br>Moderate |
| 7/19 | Sibley Cemetery 1 mile north Sibley power plant | Virginia creeper | $SO_2$ | Severe |
| 7/19 | Haynes residence 4 miles west Sibley power plant | Clematic<br>Honeysuckle | $SO_2$<br>$SO_2$ | Moderate<br>Moderate |
| 7/19 | Park St. near Light St. about a mile from Sugar Creek Refinery | Redbud | $SO_2$, acid mist | Extensive |

Table 18. SUMMARY OF TYPE AND EXTENT[a] OF LEAF DAMAGE ON EXPERIMENTAL VEGETATION

| Vegetation | Period | Waterworks | Police Garage | Morse School |
|---|---|---|---|---|
| Tobacco | 1 | $O_3$[b] + $SO_2$[c] (S) | $O_3$ + PAN[d] (M) | $O_3$ + $SO_2$ (S) |
| | 2 | $O_3$ (E) | $O_3$ (M) | $O_3$ (M) |
| Pinto bean | 1 | PAN (M) | PAN (E) | PAN (E) |
| | 2 | PAN (M) | None | PAN (M) |
| Begonia | 1 | $O_3$ (E) | Chlorosis (M) | Chlorosis (M) |
| | 2 | Chlorosis (M) | Chlorosis (T) | Chlorosis (M) |
| Petunia | 1 | Chlorosis (M) | Chlorosis (M) | Chlorosis (M) |
| | 2 | Chlorosis (M) | Chlorosis (T) | Chlorosis (M) |
| Geranium | 1 | Chlorosis (M) | Chlorosis (M) | Chlorosis (M) |
| | 2 | Chlorosis (M) | Chlorosis (T) | Chlorosis (M) |
| Corn | 1 | Chlorosis (T) | Chlorosis (T) | Chlorosis (E) |
| | 2 | Chlorosis (M) | Chlorosis (T) | Chlorosis (M) |

[a] T (trace) indicates 0 to 5 percent of leaf area damaged;
M (moderate) indicates 5 to 25 percent;
E (extensive) indicates 25 to 50 percent; and
S (severe) indicates greater than 50 percent.

[b] $O_3$ - ozone.

[c] $SO_2$ - sulfur dioxide.

[d] PAN - peroxyacetyl nitrate.

Relatively low concentrations of ozone and sulfur dioxide, when mixed, will cause damage to vegetation. Evidence of damage from mixtures of these pollutants was observed on vegetation at both the Waterworks and Morse School exposure chambers. The combination of ozone and sulfur dioxide reduces the injury threshold of the leaf tissue and increases the damage beyond that from the individual pollutants.

In addition to tissue destruction, the growth of all specimen plants was suppressed. Table 19 lists the percentage by which exposed specimens were smaller than the control specimens of the same age. A suppression value of 30 percent means that the plant growth in an exposure chamber was estimated by visual comparison to be 30 percent less than that of a similar plant grown in the Waterworks control chamber. Table 20 summarizes the air pollution effects on the tobacco plants grown in the exposure chambers during the study period.

Table 19. GROWTH SUPPRESSION OF EXPERIMENTAL VEGETATION[a]
(percent less than control)

| Vegetation | Waterworks | Police Garage | Morse School | Waterworks Control |
|---|---|---|---|---|
| Tobacco | 30 | 20 | 30 | 0 |
| Pinto bean | 25 | 15 | 30 | 0 |
| Petunia | 40 | 15 | 40 | 0 |
| Geranium | 25 | 25 | 30 | 0 |
| Begonia | 50 | 15 | 50 | 0 |
| Corn | 25 | 15 | 25 | 0 |

[a] Estimated by visual comparison

Table 20. COMPARISON OF EXPOSED AND CONTROL TOBACCO PLANT GROWTH BETWEEN 7/17/67 - 9/5/67

| | Waterworks | Police Garage | Morse School | Control |
|---|---|---|---|---|
| Percent of leaf area damaged | 30 | 20 | 30 | 0 |
| Diameter of stem, in. | 0.61 | 0.62 | 0.56 | 0.73 |
| Stem cross-section area, in.$^2$ | 0.29 | 0.30 | 0.25 | 0.42 |
| Cross-section area, percent less than control | 30 | 30 | 40 | 0 |
| Root system weight, grams | 405 | 428 | 328 | 576 |
| Percent root system weight less than control | 30 | 26 | 43 | 0 |

## Material Effects Measurements

Six stations of the Interstate Surveillance Project were operated in the study area during 1967. Five of these stations coincided with existing air-monitoring stations. The other station was used only as a part of the Interstate Surveillance Project. These stations are identified in Table C-1 of Appendix C.

Zinc and steel corrosion, dye fading, rubber deterioration, silver tarnishing, Nylon deterioration, sulfation, dustfall, and wind-blown particulates were all measured at these stations. These results are summarized in Table 21.

The average corrosion rates in the Kansas City study area for zinc and steel are 0.04 and 0.7 mils penetration per year, respectively. During 1966*, when 60 Interstate Surveillance Project (ISP) stations were in operation, these corrosion rates were exceeded by 75 and 90 percent of the stations, respectively. Thus by comparison, the corrosion rates in the study area are well below average.

Dye fading was found to be moderate in the Kansas City area. In 1967, with about 125 ISP stations operating, 50 percent of these stations exhibited dye-fading rates for the first 3 quarters of the year of less than 21, 19, and 22 Judd units for the nitrogen-dioxide-sensitive fabric and 12, 19, and 23 Judd units for the ozone-sensitive fabric. In Kansas City, the nitrogen-dioxide-sensitive fabric faded slightly more in the downtown areas, and the ozone-sensitive fabric faded substantially more in the suburban areas.

The rubber-cracking rate, by comparison to national averages, was found to be slightly above average. In 1966*, 50 percent of the ISP stations had cracking rates of less than 92 microns per week and 75 percent had rates of less than 171 microns per week. Rubber cracking is more severe in the suburban Kansas City area than in the downtown locations; therefore, there is agreement between the rubber cracking, an oxidant indicator, and the ozone dye-fading results.

In 1967, 50 percent of the ISP stations had a silver tarnishing rate of less than 58 percent reflectance loss; 75 percent of the stations had values of less than 76 percent. The Kansas City area values are considered to be moderate by comparison. Results from the downtown Kansas City, Kansas, station indicate that there is probably a source of hydrogen sulfide in this area.

Nylon deterioration is generally caused by acidic particles. During 1967, 75 percent of the ISP stations had no breaks and 90 percent averaged less than 24

---

* 1967 frequency data not available

Table 21. INTERSTATE SURVEILLANCE PROJECT MATERIAL EFFECTS DATA - 1967

| Material | Effect | Units of effect | Reporting description | Station number | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 9 | 10 | 14 | 20 | 27 | NA |
| Zinc | Corrosion | mils penetration/year | Annual | 0.05 | 0.03 | 0.04 | 0.03 | - | 0.04 |
| Steel | Corrosion | mils penetration/year | Annual | 0.7 | 0.7 | 0.3 | 0.7 | 0.8 | 0.9 |
| Fabric | Fading $NO_2$-sensitive | Judd units/90 days | Jan-Mar | 19 | 19 | 18 | 17 | 21 | 23 |
| | | | Apr-June | 18 | 17 | 19 | 16 | 16 | 19 |
| | | | July-Sept | 24 | 22 | 21 | 17 | 21 | 22 |
| | | | Oct-Dec | 17 | 15 | 12 | 13 | 15 | 12 |
| Fabric | Fading $O_3$-sensitive | Judd units/90 days | Jan-Mar | 9 | 13 | 14 | 12 | 11 | 11 |
| | | | Apr-June | 18 | 22 | 24 | 25 | 20 | 21 |
| | | | July-Sept | 23 | 24 | 28 | 26 | 24 | 21 |
| | | | Oct-Dec | 2 | 13 | 15 | 11 | 16 | 1 |
| Rubber | Cracking | microns/7 days (monthly average) | Arith mean | 82 | 100 | 135 | 143 | 106 | 104 |
| | | | Minimum | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Maximum | 161 | 180 | 229 | 317 | 269 | 232 |
| Silver | Tarnishing | percent loss of reflectance/30 days | Arith mean | 48 | 41 | 43 | 34 | 40 | 60 |
| | | | Minimum | 30 | 14 | 22 | 20 | 23 | 26 |
| | | | Maximum | 83 | 59 | 79 | 55 | 76 | 91 |
| Nylon | Deterioration | breaks/year/7 $in^2$ | Annual | 8 | 0 | 1 | 2 | 1 | 0 |
| Pb $O_2$ | $SO_2$ | mg $SO_3$/100 $cm^2$-day | Arith mean | 0.4 | 0.2 | 0.3 | 0.1 | 0.2 | 0.4 |
| | | | Minimum | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Maximum | 0.9 | 0.4 | 0.7 | 0.3 | 0.6 | 0.5 |
| Dustfall | Soiling | tons/$mi^2$-mo | Arith mean | 17 | 11 | 14 | 8 | 17 | 28 |
| | | | Minimum | 11 | 6 | 6 | 3 | 11 | 14 |
| | | | Maximum | 42 | 22 | 28 | 17 | 25 | 34 |
| Wind blown particulates | Soiling | particles/$mm^2$ | Arith mean | 36 | 20 | 20 | 17 | 41 | 34 |
| | | | Minimum | 12 | 5 | 7 | 4 | 21 | 11 |
| | | | Maximum | 71 | 55 | 47 | 56 | 70 | 71 |

breaks. The Kansas City results indicate that acid aerosols are found in the Kansas City, Missouri, area.

In 1967, 50 percent of the ISP stations had dustfall rates of less than 14 tons/$mi^2$-mo, while 75 percent had rates of less than 22 tons/$mi^2$-mo. The Kansas City area results are, by comparison, moderate except for the downtown Kansas City, Kansas, results, which are moderate to high.

In 1967, 25 and 50 percent of the ISP stations had a wind blown particulates rate of less than 17 and 34 particles/$mm^2$, respectively. The Kansas City area results fall within this range.

## EMISSION INVENTORY

An inventory of pollutant emissions from the various sources in the seven-county Kansas City, Kansas - Kansas City, Missouri, area was completed for calendar year 1966. The pollutants inventoried were sulfurous compounds (calculated as $SO_2$ and hereafter referred to as $SO_x$ or sulfur oxides), particulates, hydrocarbons (calculated as methane), and carbon monoxide. The surveyed emissions were from stationary and mobile fuel combustion sources, industrial processes, evaporative losses, and solid-waste burning.

The air contaminants discharged to the atmosphere annually from sources in the study area are listed in Tables 22 through 25 by source category. These tables show that 125,000 tons of sulfur oxides, 60,000 tons of particulates, 233,000 tons of hydrocarbons, and 744,000 tons of carbon monoxide were emitted during 1966 in the seven-county area. The major portion of these pollutants was generated in the Kansas City core area. Sources are concentrated in the highly industrialized Missouri, Kansas, and Blue River Valleys, and the densely populated and commercialized districts of the city itself.

In general, the pollutant emissions by state are somewhat similar (Table 26). The patterns of fuel usage at stationary sources and mobile source movement are nearly the same for Kansas and Missouri portions of the study area. Most of the process and refuse-burning emissions are generated in Kansas, and most of the stationary fuel combustion emissions are generated in Missouri. The Missouri portion of the study area has the larger population and most of the steam-electric power plants.

Table 22. SULFUR OXIDES EMISSIONS (AS $SO_2$) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| | Residential fuel | | | | | Commercial and governmental fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | 140 | 27 | - | Neg[a] | 167 | 100 | 34 | 37 | Neg | 171 |
| Clay | 140 | 49 | 3 | 1 | 193 | 350 | 41 | 98 | Neg | 489 |
| Jackson | 780 | 130 | 16 | 6 | 932 | 3,490 | 410 | 1,980 | 2 | 5,882 |
| Platte | 120 | 28 | - | Neg | 148 | 68 | 8 | 19 | Neg | 95 |
| Missouri subtotal | 1,180 | 234 | 19 | 7 | 1,140 | 4,008 | 493 | 2,134 | 2 | 6,637 |
| Johnson | 270 | 27 | - | 2 | 299 | 2,900 | 11 | 230 | Neg | 3,141 |
| Leavenworth | 210 | 19 | - | Neg | 229 | 77 | 5 | 72 | Neg | 154 |
| Wyandotte | 280 | 24 | - | 2 | 306 | 390 | 17 | 44 | Neg | 451 |
| Kansas subtotal | 760 | 70 | - | 4 | 834 | 3,367 | 33 | 346 | Neg | 3,746 |
| Area total | 1,940 | 304 | 19 | 11 | 2,274 | 7,375 | 526 | 2,480 | 2 | 10,383 |

[a] Negligible.

Table 22 (continued). SULFUR OXIDES EMISSIONS (AS $SO_2$) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Industrial fuel | | | | | Power plant fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | 19 | Neg [a] | 4 | Neg | 23 | 230 | 3 | - | Neg | 233 |
| Clay | 1,030 | 9 | 160 | 1 | 1,200 | 9,070 | - | 11 | - | 9,081 |
| Jackson | 2,000 | 64 | 2,440 | 7 | 4,511 | 39,100 | - | - | 4 | 39,104 |
| Platte | 3 | 3 | 1 | Neg | 7 | - | - | - | - | - |
| Missouri subtotal | 3,052 | 76 | 2,605 | 8 | 5,741 | 48,400 | 3 | 11 | 4 | 48,418 |
| Johnson | 130 | 2 | 28 | Neg | 160 | - | - | - | - | - |
| Leavenworth | 50 | 1 | 11 | Neg | 62 | - | - | - | - | - |
| Wyandotte | 720 | 25 | 3,070 | 6 | 3,821 | 16,100 | - | - | 2 | 16,102 |
| Kansas subtotal | 900 | 28 | 3,109 | 6 | 4,043 | 16,100 | - | - | 2 | 16,102 |
| Area total | 3,952 | 104 | 5,714 | 14 | 9,784 | 64,500 | 3 | 11 | 6 | 64,520 |

[a] Negligible

Table 22 (continued). SULFUR OXIDES EMISSIONS (AS $SO_2$) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Total fuel | | | | | Mobile sources | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Gasoline vehicle | Diesel vehicle | Total motor vehicle | Aircraft | Railroad diesel | Barge diesel | Total |
| Cass | 489 | 64 | 41 | Neg[a] | 594 | 80 | 24 | 104 | - | 14 | - | 118 |
| Clay | 10,590 | 99 | 272 | 2 | 10,963 | 150 | 48 | 198 | Neg | 220 | 7 | 425 |
| Jackson | 45,370 | 604 | 4,436 | 19 | 50,429 | 1,010 | 310 | 1,320 | - | 320 | 9 | 1,649 |
| Platte | 191 | 39 | 20 | Neg | 250 | 51 | 15 | 66 | Neg | 28 | 12 | 106 |
| Missouri subtotal | 56,640 | 806 | 4,769 | 21 | 62,236 | 1,291 | 397 | 1,688 | Neg | 582 | 28 | 2,298 |
| Johnson | 3,300 | 40 | 258 | 2 | 3,600 | 250 | 75 | 325 | - | 56 | - | 381 |
| Leavenworth | 337 | 25 | 83 | Neg | 445 | 110 | 34 | 144 | - | 42 | 6 | 192 |
| Wyandotte | 17,490 | 66 | 3,114 | 10 | 20,680 | 770 | 230 | 1,000 | Neg | 350 | 3 | 1,353 |
| Kansas subtotal | 21,127 | 131 | 3,455 | 12 | 24,725 | 1,130 | 339 | 1,469 | Neg | 448 | 9 | 1,926 |
| Area total | 77,767 | 937 | 8,224 | 33 | 86,961 | 2,421 | 736 | 3,157 | Neg | 1,030 | 37 | 4,224 |

[a] Negligible

Table 22 (continued). SULFUR OXIDES EMISSIONS (AS $SO_2$) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Refuse disposal | | | Industrial processes[b] | Grand total |
|---|---|---|---|---|---|
| | Incineration | Open burning | Total | | |
| Cass | Neg[a] | 8 | 8 | - | 720 |
| Clay | Neg | 21 | 21 | - | 11,409 |
| Jackson | Neg | 200 | 200 | 16,100 | 68,378 |
| Platte | Neg | 8 | 8 | - | 364 |
| Missouri subtotal | Neg | 237 | 237 | 16,100 | 80,871 |
| Johnson | Neg | 170 | 170 | 2,300 | 6,451 |
| Leavenworth | Neg | 19 | 19 | - | 656 |
| Wyandotte | Neg | 50 | 50 | 15,100 | 37,183 |
| Kansas subtotal | Neg | 239 | 239 | 17,400 | 44,290 |
| Area total | Neg | 476 | 476 | 33,500 | 125,161 |

[a] Negligible

[b] Includes $SO_2$ from the combustion of refinery gas.

Table 23. PARTICULATE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Residential fuel | | | | | Commercial and governmental fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | 24 | 8 | - | 9 | 41 | 18 | 10 | 3 | 3 | 34 |
| Clay | 24 | 15 | Neg[a] | 46 | 85 | 60 | 13 | 7 | 20 | 100 |
| Jackson | 130 | 40 | 1 | 320 | 491 | 590 | 130 | 69 | 120 | 909 |
| Platte | 20 | 9 | - | 7 | 36 | 12 | 3 | 1 | 3 | 19 |
| Missouri subtotal | 198 | 72 | 1 | 382 | 653 | 680 | 156 | 80 | 146 | 1,062 |
| Johnson | 34 | 8 | - | 97 | 139 | 2,330 | 4 | 11 | 19 | 2,364 |
| Leavenworth | 35 | 6 | - | 15 | 56 | 13 | 2 | 5 | 23 | 43 |
| Wyandotte | 48 | 7 | - | 94 | 149 | 67 | 5 | 3 | 19 | 94 |
| Kansas subtotal | 117 | 21 | - | 206 | 344 | 2,410 | 11 | 19 | 61 | 2,501 |
| Area total | 315 | 93 | 1 | 588 | 997 | 3,090 | 167 | 99 | 207 | 3,563 |

[a] Negligible

Table 23 (continued). PARTICULATE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI SURVEY AREA, 1966 (tons/year)

| County | Industrial fuel | | | | | Power plant fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | 19 | Neg[a] | Neg | 24 | 43 | 55 | 1 | - | 2 | 58 |
| Clay | 1,030 | 3 | 9 | 53 | 1,095 | 650 | - | Neg | - | 650 |
| Jackson | 2,000 | 20 | 130 | 360 | 2,510 | 2,000 | - | - | 79 | 2,079 |
| Platte | 3 | 1 | Neg | 6 | 10 | - | - | - | - | - |
| Missouri subtotal | 3,052 | 24 | 139 | 443 | 3,658 | 2,705 | 1 | Neg | 81 | 2,787 |
| Johnson | 130 | 1 | 2 | 13 | 146 | - | - | - | - | - |
| Leavenworth | 37 | Neg | 1 | 1 | 39 | - | - | - | - | - |
| Wyandotte | 720 | 7 | 170 | 320 | 1,217 | 2,660 | - | - | 40 | 2,700 |
| Kansas subtotal | 887 | 8 | 173 | 334 | 1,402 | 2,660 | - | - | 40 | 2,700 |
| Area total | 3,939 | 32 | 312 | 777 | 5,060 | 5,365 | 1 | - | 121 | 5,487 |

[a] Negligible

Table 23 (continued). PARTICULATE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Total fuel | | | | | Mobile sources | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Gasoline vehicle | Diesel vehicle | Total motor vehicle | Aircraft | Railroad diesel | Barge diesel | Total |
| Cass | 116 | 19 | 3 | 38 | 176 | 100 | 66 | 166 | - | 38 | - | 204 |
| Clay | 1,764 | 31 | 16 | 119 | 1,930 | 190 | 130 | 320 | 100 | 610 | 24 | 1,054 |
| Jackson | 4,720 | 190 | 200 | 879 | 5,989 | 1,270 | 840 | 2,110 | - | 870 | 27 | 3,007 |
| Platte | 35 | 13 | 1 | 16 | 65 | 63 | 45 | 108 | 230 | 76 | 33 | 447 |
| Missouri subtotal | 6,635 | 253 | 220 | 1,052 | 8,160 | 1,623 | 1,081 | 2,704 | 330 | 1,594 | 84 | 4,712 |
| Johnson | 2,494 | 13 | 13 | 129 | 2,649 | 310 | 200 | 510 | - | 150 | - | 660 |
| Leavenworth | 85 | 8 | 6 | 39 | 138 | 140 | 93 | 233 | - | 110 | 18 | 361 |
| Wyandotte | 3,495 | 19 | 173 | 473 | 4,160 | 960 | 630 | 1,590 | 18 | 950 | 10 | 2,568 |
| Kansas subtotal | 6,074 | 40 | 192 | 641 | 6,947 | 1,410 | 923 | 2,333 | 18 | 1,210 | 28 | 3,589 |
| Area total | 12,709 | 293 | 412 | 1,693 | 15,107 | 3,033 | 2,004 | 5,037 | 348 | 2,804 | 112 | 8,301 |

Table 23. (continued). PARTICULATE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Refuse disposal | | | Industrial processes | Grand total |
|---|---|---|---|---|---|
| | Incineration | Open burning | Total | | |
| Cass | Neg[a] | 310 | 310 | 18 | 708 |
| Clay | 13 | 770 | 783 | 1,890 | 5,657 |
| Jackson | 186 | 6,540 | 6,726 | 5,480 | 21,202 |
| Platte | Neg. | 230 | 230 | - | 742 |
| Missouri subtotal | 199 | 7,850 | 8,049 | 7,388 | 28,309 |
| Johnson | 10 | 6,740 | 6,750 | 230 | 10,289 |
| Leavenworth | 5 | 790 | 795 | 490 | 1,784 |
| Wyandotte | 115 | 1,940 | 2,055 | 10,500 | 19,283 |
| Kansas subtotal | 130 | 9,470 | 9,600 | 11,220 | 31,356 |
| Area total | 329 | 17,320 | 17,649 | 18,608 | 59,665 |

[a] Negligible

Table 24. HYDROCARBON EMISSIONS (AS METHANE) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Residential fuel | | | | | Commercial and governmental fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | 12 | 1 | - | Neg[a] | 13 | 9 | 2 | Neg | Neg | 11 |
| Clay | 12 | 3 | Neg | Neg | 15 | 30 | 2 | 1 | Neg | 33 |
| Jackson | 67 | 7 | Neg | Neg | 74 | 290 | 21 | 11 | Neg | 322 |
| Platte | 10 | 2 | - | Neg | 12 | 6 | Neg | Neg | Neg | 6 |
| Missouri subtotal | 101 | 13 | Neg | Neg | 114 | 335 | 25 | 12 | Neg | 372 |
| Johnson | 23 | 1 | - | Neg | 24 | 40 | 1 | 2 | Neg | 43 |
| Leavenworth | 18 | 1 | - | Neg | 19 | 7 | Neg | 1 | Neg | 8 |
| Wyandotte | 24 | 1 | Neg | Neg | 25 | 34 | 1 | Neg | Neg | 35 |
| Kansas subtotal | 65 | 3 | Neg | Neg | 68 | 81 | 2 | 3 | Neg | 86 |
| Area total | 166 | 16 | Neg | Neg | 182 | 416 | 27 | 15 | Neg | 458 |

[a] Negligible

Table 24 (continued). HYDROCARBON EMISSIONS (AS METHANE) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Industrial fuel | | | | | Power plant fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | Neg[a] | Neg | Neg | Neg | Neg | Neg | Neg | - | Neg | Neg |
| Clay | 8 | Neg | 1 | Neg | 9 | 6 | - | Neg | - | 6 |
| Jackson | 30 | 4 | 23 | Neg | 57 | 63 | - | - | Neg | 63 |
| Platte | Neg | Neg | Neg | Neg | Neg | - | - | - | - | - |
| Missouri subtotal | 38 | 4 | 24 | Neg | 66 | 69 | Neg | Neg | Neg | 69 |
| Johnson | 1 | Neg | Neg | Neg | 1 | - | - | - | - | - |
| Leavenworth | 1 | Neg | Neg | Neg | 1 | - | - | - | - | - |
| Wyandotte | 9 | Neg | 27 | Neg | 36 | 25 | - | - | Neg | 25 |
| Kansas subtotal | 11 | Neg | 27 | Neg | 38 | 25 | - | - | Neg | 25 |
| Area total | 49 | 4 | 51 | Neg | 104 | 94 | Neg | Neg | Neg | 94 |

[a] Negligible

Table 24. (continued). HYDROCARBON EMISSIONS (AS METHANE) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Total fuel | | | | | Mobile sources | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Gasoline vehicle exhaust blowby | Gasoline vehicle evaporation | Total gasoline vehicle | Diesel vehicle | Total motor vehicle | Aircraft | Railroad diesel | Barge diesel | Total |
| Cass | 21 | 3 | Neg[a] | Neg | 24 | 2,860 | 920 | 3,780 | 32 | 3,862 | - | 470 | - | 4,332 |
| Clay | 56 | 5 | 2 | Neg | 63 | 5,580 | 1,800 | 7,380 | 160 | 7,540 | 470 | 750 | 28 | 8,788 |
| Jackson | 450 | 32 | 34 | Neg | 516 | 35,500 | 11,400 | 46,900 | 1,030 | 47,930 | - | 1,130 | 34 | 49,094 |
| Platte | 16 | 2 | Neg | Neg | 18 | 1,860 | 600 | 2,460 | 54 | 2,514 | 1,150 | 94 | 40 | 3,798 |
| Missouri subtotal | 543 | 42 | 36 | Neg | 621 | 45,800 | 14,720 | 60,520 | 1,326 | 61,846 | 1,620 | 2,444 | 102 | 66,012 |
| Johnson | 64 | 2 | 2 | Neg | 68 | 9,010 | 2,900 | 11,900 | 250 | 12,150 | - | 190 | 83 | 12,423 |
| Leavenworth | 26 | 1 | 1 | Neg | 28 | 4,000 | 1,290 | 5,290 | 120 | 5,410 | - | 140 | 23 | 5,573 |
| Wyandotte | 92 | 2 | 27 | Neg | 121 | 27,400 | 8,820 | 36,200 | 770 | 36,970 | 1,650 | 1,180 | 14 | 39,814 |
| Kansas subtotal | 182 | 5 | 30 | Neg | 217 | 40,410 | 13,010 | 53,390 | 1,140 | 54,530 | 1,650 | 1,510 | 120 | 57,810 |
| Area total | 725 | 47 | 66 | Neg | 838 | 86,210 | 27,730 | 113,910 | 2,466 | 116,376 | 3,270 | 3,954 | 222 | 123,822 |

[a] Negligible

Table 24 (continued). HYDROCARBON EMISSIONS (AS METHANE) IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI SURVEY AREA, 1966
(tons/year)

| County | Gasoline handling | Refuse disposal |  |  | Industrial processes |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  |  | Incineration | Open burning | Total | Dry cleaning | Solvent and industrial | Total | Grand total |
| Cass | 270 | Neg[a] | 810 | 810 | 70 | 2,150 | 2,220 | 7,656 |
| Clay | 520 | 3 | 1,930 | 1,933 | 220 | 4,480 | 4,700 | 16,004 |
| Jackson | 3,340 | 220 | 14,200 | 14,420 | 1,280 | 32,800 | 34,080 | 101,450 |
| Platte | 170 | Neg | 670 | 670 | 51 | 530 | 581 | 5,237 |
| Missouri subtotal | 4,300 | 223 | 17,610 | 17,833 | 1,621 | 39,960 | 41,581 | 130,347 |
| Johnson | 850 | 2 | 11,700 | 11,702 | 340 | 2,030 | 2,370 | 27,413 |
| Leavenworth | 380 | 1 | 1,350 | 1,351 | 100 | 100 | 200 | 7,532 |
| Wyandotte | 2,590 | 23 | 3,360 | 3,383 | 380 | 21,300 | 21,680 | 67,588 |
| Kansas subtotal | 3,820 | 26 | 16,410 | 16,436 | 820 | 23,430 | 24,250 | 102,533 |
| Area total | 8,120 | 249 | 34,020 | 34,269 | 2,441 | 63,390 | 65,831 | 232,880 |

[a] Negligible

Table 25. CARBON MONOXIDE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Residential fuel | | | | | Commercial and governmental fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | 61 | 1 | - | Neg[a] | 62 | 45 | 2 | Neg | Neg | 47 |
| Clay | 59 | 3 | Neg | 1 | 63 | 150 | 2 | 1 | Neg | 153 |
| Jackson | 330 | 7 | Neg | 6 | 343 | 1,460 | 21 | 11 | 2 | 1,494 |
| Platte | 50 | 2 | - | Neg | 52 | 29 | Neg | Neg | Neg | 29 |
| Missouri subtotal | 500 | 13 | Neg | 7 | 520 | 1,684 | 25 | 12 | 2 | 1,723 |
| Johnson | 120 | 1 | - | 2 | 123 | 160 | 1 | 2 | Neg | 163 |
| Leavenworth | 87 | 1 | - | Neg | 88 | 33 | Neg | 1 | Neg | 34 |
| Wyandotte | 120 | 1 | - | 2 | 123 | 170 | 1 | Neg | Neg | 171 |
| Kansas subtotal | 327 | 3 | - | 4 | 334 | 363 | 2 | 3 | Neg | 368 |
| Area total | 827 | 16 | Neg | 11 | 854 | 2,047 | 27 | 15 | 2 | 2,091 |

[a] Negligible.

Table 25 (continued). CARBON MONOXIDE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Industrial fuel | | | | | Power plant fuel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total |
| Cass | 1 | Neg[a] | Neg | 1 | 2 | 1 | Neg | - | Neg | 1 |
| Clay | 24 | Neg | 1 | Neg | 25 | 15 | - | Neg | - | 15 |
| Jackson | 89 | 4 | 23 | 7 | 123 | 160 | - | - | Neg | 160 |
| Platte | Neg | Neg | Neg | Neg | Neg | - | - | - | - | - |
| Missouri subtotal | 114 | 4 | 24 | 8 | 150 | 176 | Neg | Neg | Neg | 176 |
| Johnson | 3 | Neg | Neg | Neg | 3 | - | - | - | - | - |
| Leavenworth | 3 | Neg | Neg | Neg | 3 | - | - | - | - | - |
| Wyandotte | 29 | 1 | 27 | 6 | 63 | 64 | - | - | Neg | 64 |
| Kansas subtotal | 35 | 1 | 27 | 6 | 69 | 64 | - | - | Neg | 64 |
| Area total | 149 | 5 | 51 | 14 | 219 | 240 | Neg | Neg | Neg | 240 |

[a] Negligible.

Table 25 (continued). CARBON MONOXIDE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Total fuel | | | | | Mobile sources | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bituminous coal | Distillate oil | Residual oil | Natural gas | Total | Gasoline vehicle | Diesel vehicle | Total motor vehicle | Aircraft | Railroad deisel | Barge diesel | Total |
| Cass | 108 | 3 | Neg[a] | 1 | 112 | 23,000 | 36 | 23,036 | - | 21 | - | 23,057 |
| Clay | 248 | 5 | 2 | 1 | 256 | 44,800 | 72 | 44,872 | 810 | 330 | 13 | 46,025 |
| Jackson | 2,039 | 32 | 34 | 15 | 2,120 | 285,000 | 450 | 285,450 | - | 500 | 15 | 285,965 |
| Platte | 79 | 2 | Neg | Neg | 81 | 15,000 | 24 | 15,024 | 2,120 | 42 | 18 | 17,204 |
| Missouri subtotal | 2,474 | 42 | 36 | 17 | 2,569 | 367,800 | 582 | 368,382 | 2,930 | 893 | 46 | 372,251 |
| Johnson | 283 | 2 | 2 | 2 | 289 | 75,500 | 110 | 75,610 | - | 190 | 83 | 75,883 |
| Leavenworth | 123 | 1 | 1 | Neg | 125 | 32,200 | 51 | 32,251 | - | 140 | 62 | 32,453 |
| Wyandotte | 383 | 3 | 27 | 8 | 421 | 221,000 | 340 | 221,340 | 6,170 | 520 | 6 | 228,036 |
| Kansas subtotal | 789 | 6 | 30 | 10 | 835 | 328,700 | 501 | 329,201 | 6,170 | 850 | 151 | 336,372 |
| Area total | 3,263 | 48 | 66 | 27 | 3,404 | 696,500 | 1,083 | 697,583 | 9,100 | 1,743 | 197 | 708,623 |

[a] Negligible.

Table 25 (continued). CARBON MONOXIDE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Refuse disposal | | | Industrial processes | Grand total |
|---|---|---|---|---|---|
| | Incineration | Open burning | Total | | |
| Cass | Neg[a] | 520 | 520 | - | 23,689 |
| Clay | 24 | 1,260 | 1,284 | - | 47,565 |
| Jackson | 1,680 | 11,200 | 12,880 | - | 300,965 |
| Platte | Neg | 370 | 370 | - | 17.655 |
| Missouri subtotal | 1,704 | 13,350 | 15,054 | - | 389,874 |
| Johnson | 21 | 11,800 | 11,821 | - | 87,993 |
| Leavenworth | 11 | 1,400 | 1,411 | - | 33,989 |
| Wyandotte | 490 | 3,490 | 3,980 | - | 232,437 |
| Kansas subtotal | 522 | 16,690 | 17,212 | - | 354,419 |
| Area total | 2,226 | 30,040 | 32,266 | - | 744,293 |

[a] Negligible

## Table 26. PERCENTAGE OF POLLUTANT EMISSIONS CONTRIBUTED BY EACH SOURCE CATEGORY IN MISSOURI, KANSAS, AND TOTAL STUDY AREA, 1966

| Source Category | Missouri | | | | Kansas | | | | Study Area | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_x$ | Part. | HC | CO | $SO_x$ | Part. | HC | CO | $SO_x$ | Part. | HC | CO |
| Combustion fuels-station sources | | | | | | | | | | | | |
| Residential | 1.8 | 2.3 | 0.1 | 0.1 | 1.7 | 1.1 | 0.1 | 0.1 | 1.7 | 1.7 | 0.1 | 0.1 |
| Commercial and governmental | 8.2 | 3.8 | 0.3 | 0.4 | 7.7 | 7.9 | 0.1 | 0.1 | 8.0 | 6.0 | 0.2 | 0.3 |
| Industrial | 7.1 | 12.9 | 0.1 | Neg[a] | 8.3 | 4.5 | Neg | Neg | 7.6 | 8.5 | 0.1 | Neg |
| Power plants | 59.9 | 9.8 | Neg | Neg | 33.1 | 8.6 | Neg | Neg | 49.8 | 9.2 | Neg | Neg |
| Fuel subtotal | 77.0 | 28.8 | 0.5 | 0.5 | 50.8 | 22.1 | 0.2 | 0.2 | 67.1 | 25.4 | 0.4 | 0.4 |
| Non-combustion fuels | | | | | | | | | | | | |
| Industrial processes | 19.9 | 26.1 | 31.9 | - | 44.8 | 36.0 | 23.7 | - | 29.3 | 31.0 | 28.3 | - |
| Motor vehicles | 2.1 | 9.6 | 47.4 | 94.6 | 3.0 | 7.5 | 53.2 | 93.0 | 2.4 | 8.4 | 49.9 | 93.8 |
| Gasoline handling | - | - | 3.3 | - | - | - | 3.7 | - | - | - | 3.5 | - |
| Incineration | Neg | 0.7 | 0.2 | 0.4 | Neg | 0.4 | Neg | 0.1 | Neg | 0.6 | 0.1 | 0.3 |
| Open burning | 0.3 | 27.7 | 13.5 | 3.5 | 0.5 | 30.1 | 16.0 | 4.8 | 0.4 | 28.9 | 14.6 | 4.1 |
| Railroads | 0.7 | 5.6 | 1.9 | 0.2 | 0.9 | 3.9 | 1.5 | 0.2 | 0.8 | 4.7 | 1.7 | 0.2 |
| Aircraft | Neg | 1.2 | 1.2 | 0.8 | Neg | Neg | 1.6 | 1.7 | Neg | 0.8 | 1.4 | 1.2 |
| Barges | Neg | 0.3 | 0.1 | Neg | Neg | Neg | 0.1 | Neg | Neg | 0.2 | 0.1 | Neg |
| Non-fuel subtotal | 23.0 | 71.2 | 99.5 | 99.5 | 49.2 | 77.9 | 99.8 | 99.8 | 32.9 | 74.6 | 99.6 | 99.6 |
| Total pollutant, tons/year | 80,871 | 28,309 | 130,347 | 389,874 | 44,290 | 31,356 | 102,533 | 354,419 | 125,161 | 59,665 | 232,880 | 744,293 |

[a] Negligible

Sulfur oxides (97 percent of which is $SO_2$, the remainder being $SO_3$ or sulfuric acid mist) emitted in the survey area are mainly generated by the combustion of sulfur-bearing fuels at stationary sources. As shown in Table 26 and Figure 9, these fuels contribute 67 percent of the $SO_x$ in the survey area. The other 33 percent of the $SO_x$ is emitted by industrial processes (29 percent), motor vehicles (2 percent), railroads (1 percent), and open burning of refuse (less than 1 percent).

The sulfur oxides from fuel combustion reflect fuel quantities and sulfur contents. Area-wide average sulfur contents (Appendix D) were used for unsurveyed fuel-burning sources. At any surveyed source, the reported fuel sulfur content was used for emission calculations.

As shown in Table 26 and Figure 10, particulate emissions in the Kansas City survey area are mainly generated by combustion of fuel at stationary sources (25 percent of study area total), industrial process losses (31 percent), open burning of refuse (29 percent), and motor vehicles (8 percent). The other 7 percent of the particulates are emitted by railroad and barge diesel fuel usage, refuse incineration, and aircraft operations.

The 60,000 tons of particulates emitted in the survey area are principally solid matter, but contain some finely divided liquid aerosols. These liquid aerosols include oil mists from processes,such as asphalt blowing, and minute acid particles from sulfuric acid manufacturing plants. Solid particulates include both organic and inorganic materials from fuel combustion; charred cellulose and ash from refuse burning; oxidized gasoline additives (mainly lead compounds) from automobiles; mineral dust from rock crushing and handling, asphaltic and concrete batch plants and cement manufacturing plants; metallurgical fume; petroleum catalyst fines; grain dust from grain milling and handling; glass fibers from glass fiber manufacture; and various other organic and inorganic dusts from industrial processes.

The particulates inventory for combustion fuels reflects fuel quantities, ash contents, and, in some instances, control equipment. For any surveyed source, the reported fuel ash content and control equipment collection efficiencies or stack sampling results were used for emission calculations. Average ash contents (Appendix D) and control equipment efficiencies were used for the many small coal-combustion sources distributed throughout the area. For nearly all such area-wide sources, it was assumed that no control equipment is used on coal-fired units.

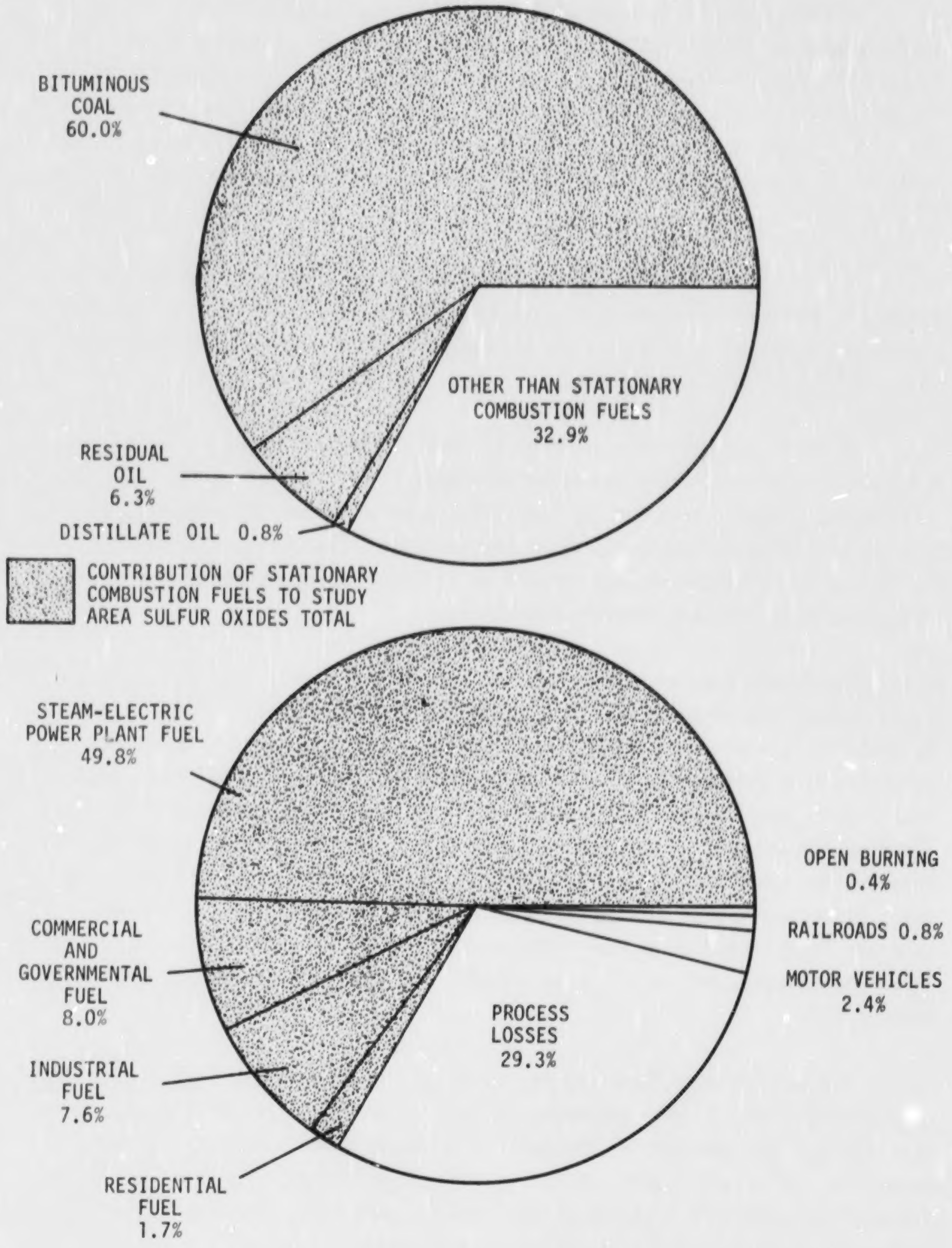


**Figure 9.** Sulfur oxides emitted in total study area by various stationary-combustion fuels (top) and by various sources (bottom).

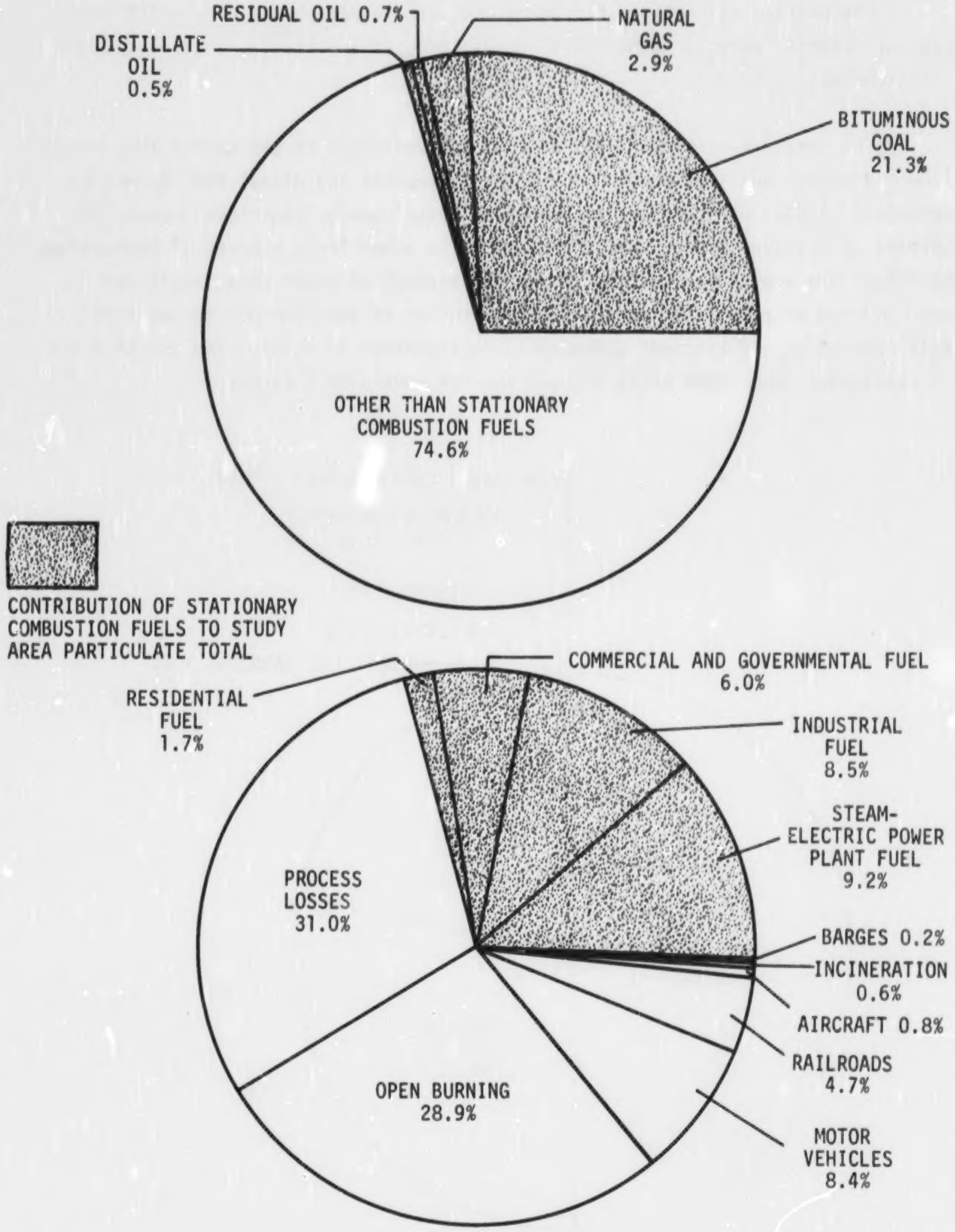


**Figure 10. Particulates emitted in total study area by various stationary-combustion fuels (top) and by various sources (bottom).**

The particulate emissions from refuse burning were based on quantity and type of material burned, method of disposal, and, if applicable, control equipment efficiencies.

The greatest portion of the hydrocarbon emissions in the survey area emanate from the blowby and incomplete combustion of gasoline and diesel fuel by motor vehicles. Table 26 and Figure 11 show that these sources contribute nearly 50 percent of the area hydrocarbon emissions. The other large sources of hydrocarbon emissions are industrial process losses (28 percent of study area total) and open burning of refuse (15 percent). Evaporation of gasoline during handling; railroad, barge, and aircraft operations; incineration of refuse; and use of fuels in stationary combustion units account for the remaining 7 percent.

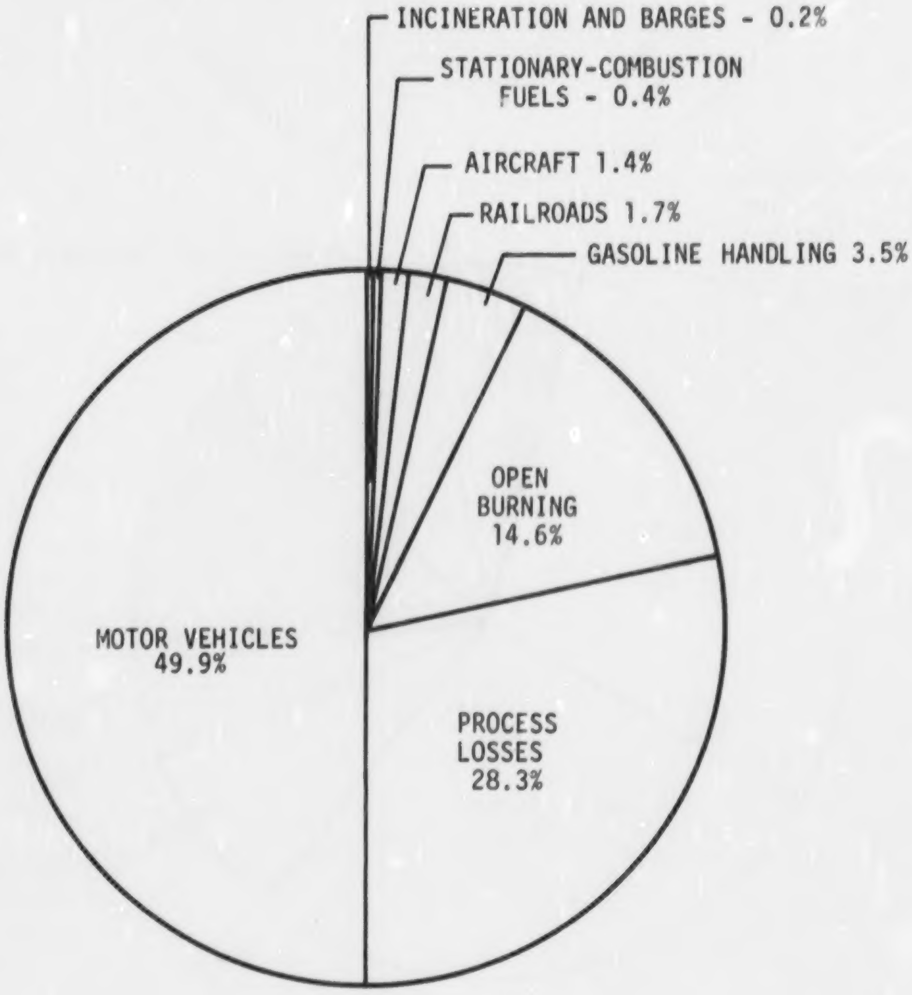


Figure 11. Hydrocarbons emitted in the total study area by various sources.

Carbon monoxide emissions for the study area can nearly all be attributed to the combustion of gasoline and diesel fuel by motor vehicles. As is shown in Table 26 and Figure 12, motor vehicles contribute almost 94 percent of the annual carbon monoxide total. The other 6 percent of the carbon monoxide is emitted by open burning and incineration of refuse, stationary fuel combustion sources, and railroad and aircraft operations.

The emission calculations for carbon monoxide from motor vehicles are based on amounts and types of gasoline and diesel fuel used and on the operating conditions of the vehicles.

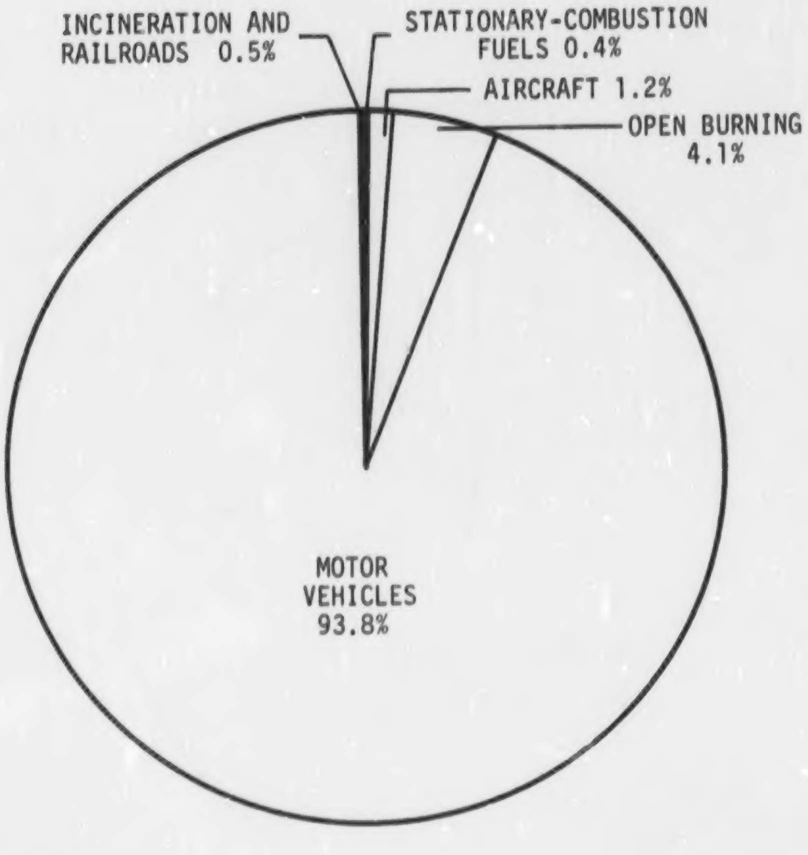


Figure 12. Carbon monoxide emitted in total study area by various sources.

Combustion of Fuel at Stationary Sources

Bituminous coal, distillate and residual oil, and natural gas were considered to be the only fuel types with significant use in the survey area for space, water, and process heating. Because of the proximity of various gas fields, natural gas is the principal fuel used in the area for these purposes. Petroleum refinery gas and coke were used at various industrial and power plant sites. The quantities of fuels burned are listed by county, fuel, and source type in Table 27, with emissions listed in Tables 22 through 25.

Annual consumptions of fuel for stationary sources are: 1.3 million tons of bituminous coal, 48.7 million gallons of distillate oil, 67.8 million gallons of residual oil, and 171 billion cubic feet of natural gas. The fraction of the total heat supplied by each of these fuels is shown in Figure 13.

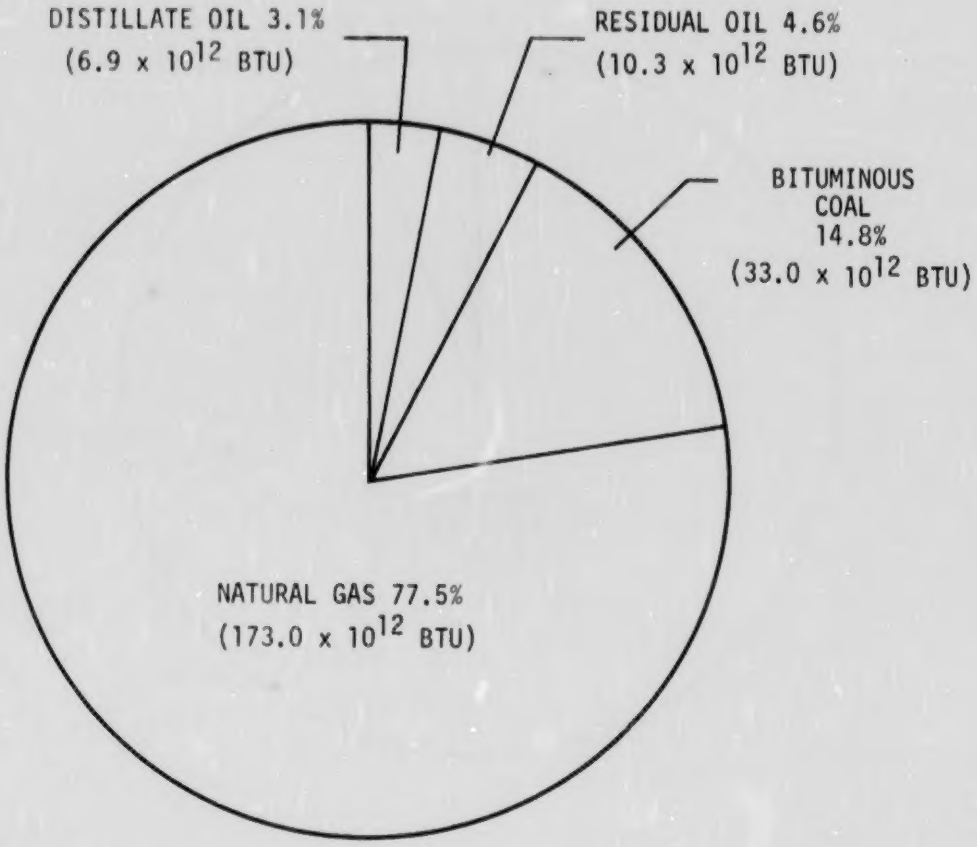


Figure 13. Heat supplied by principal stationary combustion fuels in total study area.

Table 27. FUEL BALANCE FOR KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966

| County | Residential fuel | | | | Commercial and governmental fuel | | | |
|---|---|---|---|---|---|---|---|---|
| | Bituminous coal, tons | Distillate oil, 1000 gal | Residual oil, 1000 gal | Natural gas, $10^6$ ft$^3$ | Bituminous coal, tons | Distillate oil, 1000 gal | Residual oil, 1000 gal | Natural gas, $10^6$ ft$^3$ |
| Cass | 2,450 | 1,390 | - | 930 | 1,780 | 1,750 | 420 | 310 |
| Clay | 2,350 | 2,560 | 40 | 4,550 | 5,960 | 2,160 | 1,120 | 2,040 |
| Jackson | 13,400 | 6,670 | 180 | 32,100 | 59,200 | 21,500 | 11,500 | 12,100 |
| Platte | 2,020 | 1,460 | - | 740 | 1,160 | 420 | 220 | 268 |
| Missouri subtotal | 20,220 | 12,080 | 220 | 38,320 | 68,100 | 25,830 | 13,260 | 14,718 |
| Johnson | 4,660 | 1,390 | - | 9,720 | 42,200 | 590 | 1,770 | 1,870 |
| Leavenworth | 3,490 | 1,000 | - | 1,470 | 1,300 | 270 | 830 | 2,290 |
| Wyandotte | 4,750 | 1,230 | - | 9,390 | 6,700 | 870 | 510 | 1,880 |
| Kansas subtotal | 12,900 | 3,620 | - | 20,580 | 50,200 | 1,730 | 3,110 | 6,040 |
| Area total | 33,120 | 15,700 | 220 | 58,900 | 118,300 | 27,560 | 16,370 | 20,758 |

- insignificant

Table 27 (continued). FUEL BALANCE FOR KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966

| County | Industrial fuel | | | | Power plant | | | |
|---|---|---|---|---|---|---|---|---|
| | Bituminous coal, tons | Distillate oil, 1000 gal | Residual oil, 1000 gal | Natural gas, $10^6$ ft$^3$ | Bituminous coal, tons | Distillate oil, 1000 gal | Residual oil, 1000 gal | Natural gas, $10^6$ ft$^3$ |
| Cass | 320 | 20 | 50 | 2,410 | 3,000 | 140 | - | 540 |
| Clay | 16,500 | 470 | 1,550 | 5,300 | 142,000 | - | 120 | - |
| Jackson | 58,600[a] | 3,330 | 21,700 | 35,600[b] | 617,000[d] | - | - | 20,100 |
| Platte | 50 | 150 | 10 | 600 | - | - | - | - |
| Missouri subtotal | 75,470 | 3,970 | 23,310 | 43,910 | 762,000 | 140 | 120 | 20,640 |
| Johnson | 2,140 | 130 | 320 | 1,280 | - | - | - | - |
| Leavenworth | 1,660 | 50 | 130 | 120 | - | - | - | - |
| Wyandotte | 18,700 | 1,110 | 27,300 | 32,200[c] | 255,000 | - | - | 8,450 |
| Kansas subtotal | 22,500 | 1,290 | 27,750 | 33,600 | 255,000 | - | - | 8,450 |
| Area total | 97,970 | 5,260 | 51,060 | 77,510 | 1,017,000 | 140 | 120 | 29,090 |

[a] Includes 3,000 tons coke

[b] Includes 8012 x $10^6$ ft$^3$ refinery gas

[c] Includes 7700 x $10^6$ ft$^3$ refinery gas

[d] Includes 24,860 tons coke

- insignificant

Table 27 (continued). FUEL BALANCE FOR KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI,
SURVEY AREA, 1966

| County | Total fuel | | | |
|---|---|---|---|---|
| | Bituminous coal, tons | Distillate oil, 1000 gal | Residual oil, 1000 gal | Natural gas, $10^6$ $ft^3$ |
| Cass | 7,550 | 3,300 | 470 | 4,190 |
| Clay | 166,810 | 5,190 | 2,830 | 11,890 |
| Jackson | 748,200 | 31,500 | 33,380 | 99,900 |
| Platte | 3,230 | 2,030 | 230 | 1,608 |
| Missouri subtotal | 925,790 | 42,020 | 36,910 | 117,588 |
| Johnson | 49,000 | 2,110 | 2,090 | 12,870 |
| Leavenworth | 6,450 | 1,320 | 960 | 3,880 |
| Wyandotte | 285,150 | 3,210 | 27,810 | 51,920 |
| Kansas subtotal | 340,600 | 6,640 | 30,860 | 68,670 |
| Area total | 1,266,390 | 48,660 | 67,770 | 186,258 |

Tables 26 and 28 and Figures 9 through 12 show the relative contributions of combustion fuels to pollutant emissions. The combustion of fuels at stationary sources contributes 67 and 25 percent, respectively, of the $SO_x$ and particulate emissons of the area totals. The burning of bituminous coal is the main source of these emissions. There is very little pollution from the combustion of fuel oil in the study area because of the small quantities burned. The only significant fuel oil emission is the 6 percent of the $SO_x$ generated by the burning of residual oil. Natural gas generally contributes a very small percentage of pollutant emissions.

Table 29 shows the largest source of pollutants from stationary combustion fuels to be bituminous coal. The burning of this fuel emits over 84 percent of each combustion fuel pollutant while contributing only 15 percent of the heat generated by all the fuels (Figure 13). Residual and distillate oil combustion produces 11 and 13 percent of the fuel $SO_x$ and hydrocarbons, respectively, but only 8 percent of the heat. Natural gas provides the remaining 77 percent of the heat requirement, but is responsible for only 11 percent of the fuel particulates and negligible amounts of the other pollutants.

Utility companies operate eight large steam-electric power plants in the study area. Five of the plants are located in the core city area and one each is located in Missouri City, Pleasant Hill, and Sibley, Missouri.

Multiple-cyclone collectors are used on most of the coal-fired units at these power plants. These devices have collection efficiencies for particulates ranging from 80 to 85 percent, by weight.

Combustion of fuels at these steam-electric power plants is a large source of sulfur oxides and particulate pollution in the area. The sulfur oxides emitted (64,500 tons annually) account for 50 percent of the area total; the particulate emissions (5500 tons annually) are 9 percent of the area total.

The emissions from public utility power plants result mainly from the large quantities of bituminous coal burned. These power plants burn nearly 80 percent of the coal used in the study area. Large quantities of natural gas are also burned at the plants. The plants obtain gas on an interruptible basis during the heating months of the winter. Thus, a large portion of this gas is used in the summer and large quantities of coal are burned during the winter months. This, combined with emissions from fuel combustion for residential and commercial space heating, tends to increase the pollutant levels in the winter.

Table 28. PERCENTAGE OF POLLUTANT EMISSIONS CONTRIBUTED BY EACH FUEL TYPE IN MISSOURI AND KANSAS PORTIONS OF STUDY AREA AND TOTAL STUDY AREA, 1966

| | Missouri | | | | Kansas | | | | Study area | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_x$ | Part. | HC | CO | $SO_x$ | Part. | HC | CO | $SO_x$ | Part. | HC | CO |
| Bituminous coal | 70.0 | 23.4 | 0.4 | 0.5 | 43.4 | 19.4 | 0.2 | 0.2 | 60.0 | 21.3 | 0.3 | 0.4 |
| Distillate oil | 1.0 | 0.9 | 0.1 | Neg[a] | 0.3 | Neg | Neg | Neg | 0.8 | 0.5 | Neg | Neg |
| Residual oil | 6.0 | 0.8 | Neg | Neg | 7.1 | 0.7 | Neg | Neg | 6.3 | 0.7 | 0.1 | Neg |
| Natural gas | Neg | 3.7 | Neg | Neg | Neg | 2.0 | Neg | Neg | Neg | 2.9 | Neg | Neg |
| Fuel combustion pollutants, tons/year | 62,236 | 8,165 | 621 | 2,569 | 24,725 | 6,949 | 217 | 835 | 86,961 | 15,114 | 838 | 3,404 |

[a] Negligible

Table 29. PERCENTAGE OF POLLUTANT EMISSIONS DUE TO COMBUSTION FUELS AT STATIONARY SOURCES IN MISSOURI AND KANSAS, AND TOTAL STUDY AREA, 1966

| | Missouri | | | | Kansas | | | | Study area | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_x$ | Part. | HC | CO | $SO_x$ | Part. | HC | CO | $SO_x$ | Part. | HC | CO |
| Bituminous coal | 91.0 | 81.3 | 87.5 | 96.4 | 85.5 | 87.4 | 83.9 | 94.5 | 89.4 | 84.1 | 86.5 | 95.9 |
| Distillate oil | 1.3 | 3.1 | 6.8 | 1.6 | 0.5 | 0.6 | 2.3 | 0.7 | 1.1 | 1.9 | 5.6 | 1.4 |
| Residual oil | 7.7 | 2.7 | 5.7 | 1.4 | 14.0 | 2.8 | 13.8 | 3.6 | 9.5 | 2.7 | 7.9 | 11.9 |
| Natural gas | Neg[a] | 12.9 | Neg | 0.6 | Neg | 9.2 | Neg | 1.2 | Neg | 11.3 | Neg | 0.8 |
| Fuel combustion pollutants, tons/year | 62,236 | 8,165 | 621 | 2,569 | 24,725 | 6,949 | 217 | 835 | 86,961 | 15,114 | 838 | 3,404 |

[a] Negligible

Fuel combustion by industrial sources accounts for 8 percent of the area $SO_x$ emissions and 8 percent of the particulates. These emissions emanate mainly from the large use of residual oil and from coal-fired boilers with no emission control devices. Of the residual oil burned in the survey area, 75 percent is used for process and space-heating by industrial plants. The burning of bituminous coal at industrial sources in boilers without emission control devices generates almost 4,000 tons of particulates per year. This amount of particulates is nearly the same as that emitted by the public utility power plants, yet the power plants burn 10 times more coal.

Commercial, governmental, and residential fuel combustion emit 12,600 tons of $SO_x$ and 4,500 tons of particulate annually. As is true with industrial fuel combustion, these $SO_x$ (10 percent of area total) and particulate (8 percent of area total) emissions are due mainly to the burning of residual oil and coal in boilers not equipped with emission control devices.

## Industrial and Commercial Process and Solvent Losses

Industrial and commercial process sources in the Kansas City survey area produce large quantities of sulfur oxides, particulates, and hydrocarbon emissions. In 1966 these sources, which are located mainly in the vicinity of the Missouri, Kansas, and Blue Rivers and in the core city area, emitted 33,500 tons of $SO_x$ (29 percent of the area total), 18,600 tons of particulate (31 percent), and 65,800 tons of hydrocarbons (28 percent). A summary of the larger industrial sources and their emissions is given in Table 30.

The main sources of $SO_x$ process emissions are petroleum refineries and sulfuric acid plants. The particulate process emissions come from various industrial operations, which include asphalt and concrete batch operations, cement manufacturing plants, ferrous and nonferrous metal operations, grain handling and milling, catalyst regenerators at petroleum refineries, glass fiber manufacture, and miscellaneous chemical manufacturing.

Collection devices for reducing emissions of particulates are provided at various process sources. Collection efficiencies of control equipment were taken into account when estimating process emissions. Ranges of collection equipment efficiencies for various process industries in the survey area are listed in Table 31.

Table 30. SUMMARY OF SELECTED INDUSTRIAL PROCESS POINT SOURCE EMISSIONS IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966 (tons/year)

| Source | $SO_x$ | Particulate | HC |
|---|---|---|---|
| Asphalt batch plants | -[a] | 430 | - |
| Cement manufacturing plants | - | 5,420 | - |
| Ferrous metal operations | - | 1,840 | 350 |
| Nonferrous metal operations | - | 1,960 | - |
| Grain handling and milling | - | 3,860 | - |
| Glass fiber manufacture | - | 1,990 | - |
| Automobile assembly plants | - | - | 14,900 |
| Petroleum refineries | 30,800[b] | 830 | 22,100 |
| Other miscellaneous chemical manufacturing | 2,700 | 780 | 2,190 |

[a] Dash indicates insignificant

[b] Includes $SO_2$ from the combustion of refinery gas

Table 31. PARTICULATE CONTROL EQUIPMENT EFFICIENCIES AT SELECTED INDUSTRIAL PROCESSES IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA

| Source | Particulate type | Collector efficiency range, % |
|---|---|---|
| Asphalt batch plants | Dust | 0-98 |
| Cement manufacturing plants | Dust | 97-99.9 |
| Ferrous metal operations | Dust and smoke | 0-98.5 |
| Grain handling and milling | Dust | 75-99.8 |
| Petroleum catalyst regenerators | Dust | 99.9 |

Hydrocarbon losses occur from the use of solvents in dry cleaning operations, automobile assembly plants, metal fabricating plants, paint and varnish industries, ink and printing industries, and in various other industrial and commercial operations that use hydrocarbon solvents, vehicles, or raw materials. Hydrocarbon process emissions occur in petroleum refineries in the various stages of processing, handling, and storing the petroleum products.

## Refuse Disposal

The amounts of refuse disposed of in the Kansas City area by the various methods are listed in Table 32. An estimated 900,000 tons of refuse is disposed of annually, 82 percent of which is burned in some type of open-burning operation. Disposal of refuse in incinerators and by open-burning accounts for 29 percent of the area's particulate emissions (17,700 tons), 15 percent of the hydrocarbons (34,300 tons), 4 percent of the carbon monoxide (32,300 tons), and less than 1 percent of the $SO_x$ (500 tons). Refuse disposal is a large source of pollutant emissions in the area primarily because of the large quantities of refuse disposed of by open-burning dumps and on site open-burning operations. Eighteen percent of the refuse is disposed of in landfills (13 percent) or by on site incineration (5 percent). The fractions of total refuse disposed of by the various methods

Table 32. REFUSE DISPOSAL IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(tons/year)

| County | Landfill | Open-burning dump | Open-burning on site | Incineration on site | Total |
|---|---|---|---|---|---|
| Cass | 4,630 | 6,890 | 7,450 | Neg | 18,970 |
| Clay | Neg[a] | 14,100 | 20,800 | 1,370 | 36,270 |
| Jackson | 25,700 | 195,000 | 89,800 | 18,300 | 328,800 |
| Platte | Neg | 3,520 | 7,320 | Neg | 10,840 |
| Missouri subtotal | 30,330 | 219,510 | 125,370 | 19,670 | 394,880 |
| Leavenworth | 8,400 | 31,820 | 1,070 | 500 | 41,790 |
| Johnson | 540 | 267,710 | 15,200 | 980 | 284,430 |
| Wyandotte | 74,000 | 78,000 | 3,630 | 23,300 | 177,930 |
| Kansas subtotal | 82,940 | 377,530 | 19,900 | 23,780 | 504,150 |
| Area total | 113,270 | 597,040 | 145,270 | 43,450 | 899,030 |

[a] Negligible

are depicted in Figure 14 and the breakdown by state is shown in Table 33. Somewhat more than half of the refuse is disposed of in the Kansas portion of the study area where eight of the area's 14 largest open-burning dumps are located.

Included in the refuse disposal category are the emissions from burning junked automobiles. The pollutant of major concern from this burning is particulates, although there are emissions of carbon monoxide and hydrocarbons. The particulate emissions from automobile burning in the Kansas City area account for less than 1 percent of the overall particulates total. Even though this source on an area-wide basis is small compared to other sources, it does present a local nuisance.

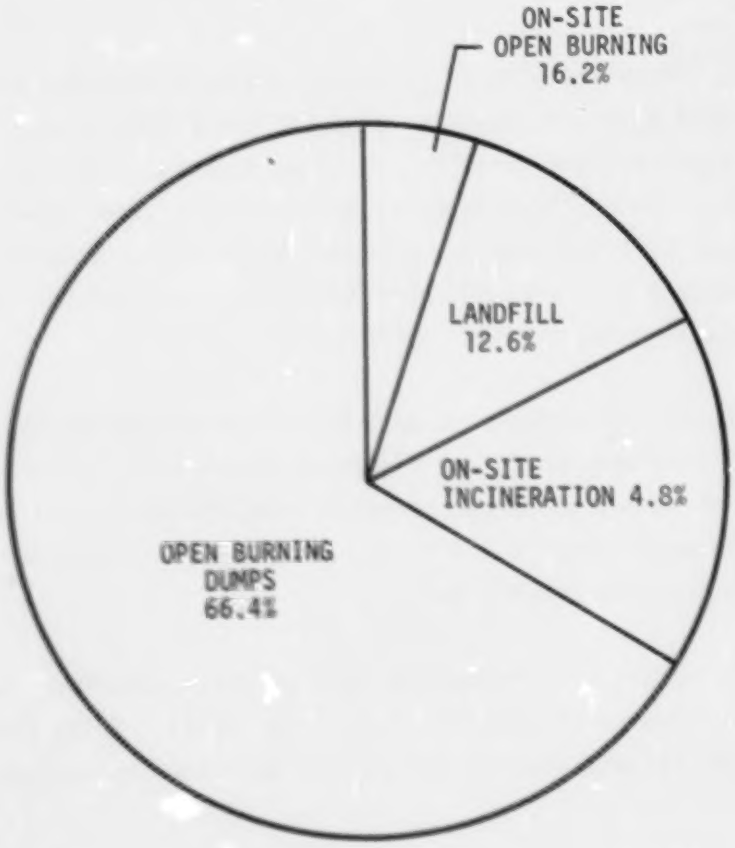


Figure 14. Refuse disposal by various methods in total study area.

Table 33. PERCENT OF REFUSE DISPOSED OF BY VARIOUS METHODS IN MISSOURI AND KANSAS PORTIONS OF STUDY AREA AND TOTAL STUDY AREA, 1966

| Disposal method | Missouri | Kansas | Study area |
|---|---|---|---|
| Landfill | 7.7 | 16.5 | 12.6 |
| Open-burning dumps | 55.6 | 74.9 | 66.4 |
| On-site open burning | 31.7 | 3.9 | 16.2 |
| On-site incineration | 5.0 | 4.7 | 4.8 |
| Total refuse, tons/yr | 394,880 | 504,150 | 899,030 |

Mobile Sources

The mobile source category of pollutant emitters includes motor vehicles (gasoline and diesel powered), railroad engines, river barges, and aircraft. The total fuel usage by motor vehicles, railroad engines, and river barges is shown in Table 34. The emission calculations for these three types of sources were based on these fuel use totals. Aircraft emissions calculations for the three major airports in the area (Mid-Continent, Fairfax, and Municipal) were based on take-off, landing, and taxi operations.

The amounts and percentages of each pollutant emitted by mobile sources are shown in Tables 22 through 26 and Figures 9 through 12. Motor vehicles are by far the greatest source of carbon monoxide (698,000 tons or 94 percent of the area total) in the area. Nearly all of the carbon monoxide emitted by motor vehicles emanates from the automobile.

Motor vehicles are also sources of half of the area's hydrocarbon pollution (116,000 tons or 50 percent of the area total). These hydrocarbons from motor vehicles include blow-by and exhaust emissions and evaporative losses.

The particulate emissions from mobile sources account for 14 percent (8,300 tons) of the area-wide particulates total. Aircraft and barges contribute 1 percent, railroads, 5 percent, and motor vehicles, the remaining 8 percent.

Mobile sources produce only 3 percent of sulfur oxides emitted in the area.

Table 34. MOBILE FUEL FOR KANSAS CITY, KANSAS-
KANSAS CITY, MISSOURI, SURVEY AREA, 1966
(thousand gallons/year)

| County | Motor vehicle diesel | Motor vehicle gasoline | Railroad diesel | Barge diesel |
|---|---|---|---|---|
| Cass | 1,200 | 20,000 | 690 | 0 |
| Clay | 2,400 | 39,000 | 11,100 | 420 |
| Jackson | 15,100 | 248,000 | 16,700 | 500 |
| Platte | 800 | 13,000 | 1,390 | 580 |
| Missouri subtotal | 19,500 | 320,000 | 29,880 | 1,500 |
| Johnson | 3,700 | 63,000 | 2,780 | 0 |
| Leavenworth | 1,700 | 28,000 | 2,080 | 330 |
| Wyandotte | 11,400 | 192,000 | 17,400 | 210 |
| Kansas subtotal | 16,800 | 283,000 | 22,260 | 540 |
| Area total | 36,300 | 603,000 | 52 140 | 2,040 |

## Gasoline Evaporation (Handling)

This source category includes the hydrocarbon losses that occur during the transfer of gasoline from storage tanks to tank trucks, from tank trucks to filling station storage tanks, and from filling station pumps to vehicles. As shown in Figure 11, it can be seen that almost 4 percent of the area-wide hydrocarbons come from this source.

## Point Sources

Any individual site in the survey area that emitted 100 tons or more per year of any single pollutant was considered to be a point source. There were 70 such sources located by this survey. These sources include 8 public utility steam-electric power plants, 44 industrial sites (fuel use, process, and refuse emissions combined), 14 open-burning dumps, and 4 miscellaneous governmental establishments.

On a yearly basis these 70 point sources contribute 110,000 tons of $SO_x$ (88 percent of total), 40,000 tons of particulates (67 percent of total), 63,000 tons of hydrocarbons (27 percent of total), and 26,000 tons of carbon monoxide (4 percent of total). Point source locations are shown on the map of Figure 15.

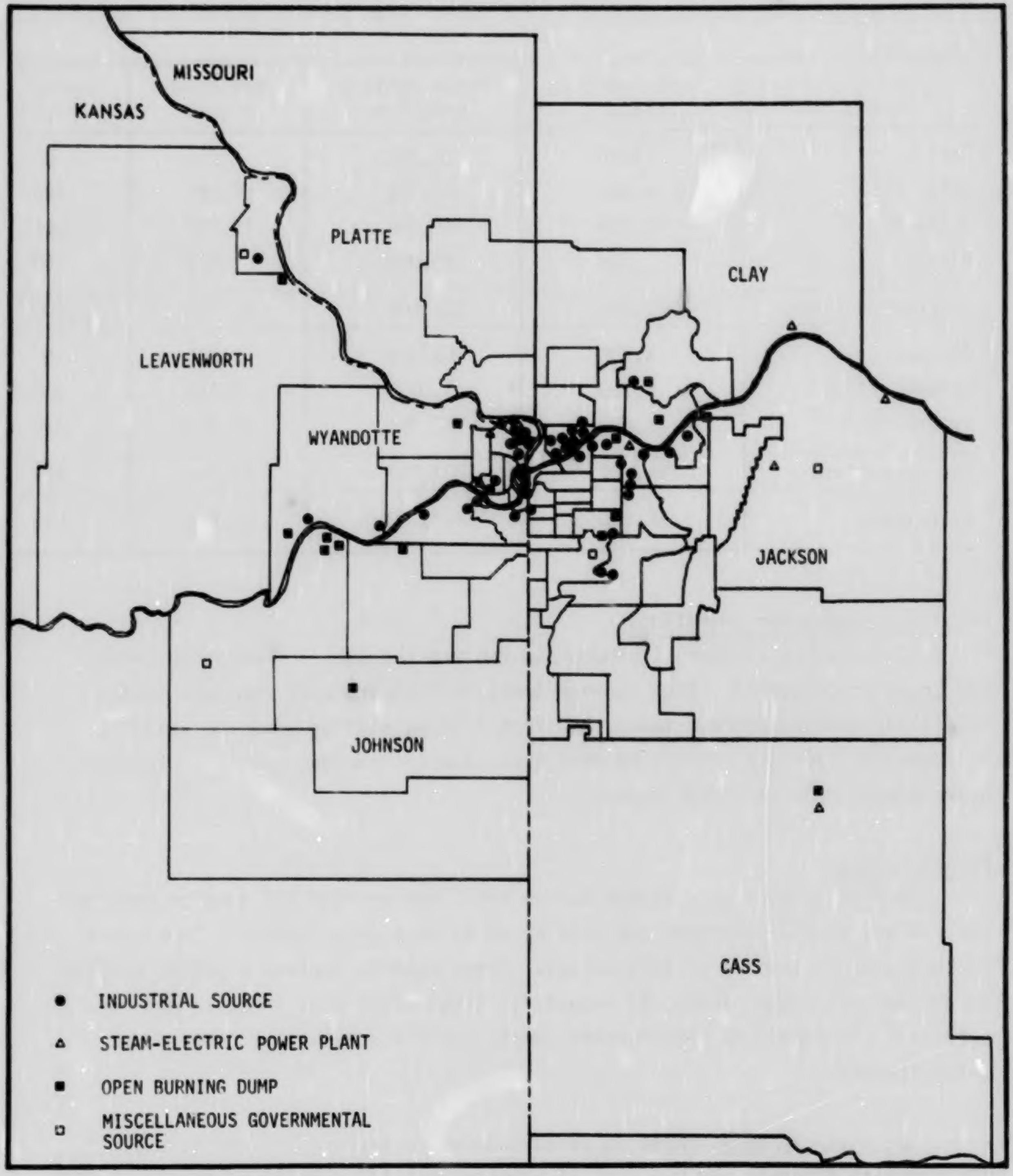

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
● INDUSTRIAL SOURCE
△ STEAM-ELECTRIC POWER PLANT
■ OPEN BURNING DUMP
□ MISCELLANEOUS GOVERNMENTAL SOURCE

**Figure 15. Point sources that emit 100 tons or more per year of a single pollutant.**

## Variation in Pollutants Due to Space-Heating

Increased fuel burning during space-heating days results in greater pollutant emissions than occur on days when space-heating is not required. This is especially true of $SO_x$ and particulate emissions, since a large portion of these emissions result from the combustion of fuel at stationary sources for space-heating purposes. The variations in emissions for minimum, average, and maximum space-heating days for $SO_x$ and particulates are shown in Tables 35 and 36. The variation in $SO_x$ emission values between a minimum and maximum space-heating day is more than threefold, while that for particulates is less than twofold.

As is seen in Table 35, space-heating at residential, commercial, governmental, and industrial establishments and power plant fuel use cause the large seasonal variation in $SO_x$ emissions. The power plant data reflect the use of interruptable gas. In the winter heating months when the space-heating natural gas demand is great, the power plants must use their standby fuel--coal or fuel oil. The variation in particulate emissions is not as great as that for $SO_x$ since a large portion of the particulates come from sources such as refuse burning and industrial process losses, which are relatively constant throughout the year.

Table 35. EMISSIONS OF SULFUR OXIDES AND PARTICULATES BY SOURCE TYPE FOR MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS IN THE KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966

| Source type | $SO_x$ |  |  | Particulates |  |  |
|---|---|---|---|---|---|---|
|  | Min | Avg | Max | Min | Avg | Max |
| Residential fuel | Neg[a] | 10 | 28 | Neg | 5 | 12 |
| Commercial and governmental fuel | Neg | 48 | 130 | Neg | 17 | 42 |
| Industrial fuel | 27 | 72 | 147 | 15 | 38 | 77 |
| Power plant fuel | 86 | 203 | 370 | 6 | 18 | 36 |
| Process emissions | 104 | 104 | 104 | 61 | 61 | 61 |
| Motor vehicles | 7 | 7 | 7 | 14 | 14 | 14 |
| Railroads | 2 | 2 | 2 | 7 | 7 | 7 |
| Aircraft | Neg | Neg | Neg | 1 | 1 | 1 |
| Barges | Neg | Neg | Neg | Neg | Neg | Neg |
| Refuse burning | 2 | 2 | 2 | 70 | 70 | 70 |
| Area total | 228 | 448 | 790 | 174 | 231 | 320 |

[a] Negligible

### Table 36. EMISSIONS OF SULFUR OXIDES AND PARTICULATES BY COUNTY FOR MINIMUM, AVERAGE, AND MAXIMUM SPACE-HEATING DAYS IN THE KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966

(tons/day)

| County | $SO_x$ | | | Particulates | | |
|---|---|---|---|---|---|---|
| | Min | Avg | Max | Min | Avg | Max |
| Cass | Neg | 3 | 9 | 2 | 3 | 4 |
| Clay | 29 | 38 | 52 | 18 | 24 | 33 |
| Jackson | 122 | 242 | 432 | 64 | 88 | 124 |
| Platte | Neg | 1 | 3 | 2 | 2 | 3 |
| Missouri subtotal | 151 | 284 | 496 | 86 | 117 | 164 |
| Johnson | 8 | 25 | 52 | 30 | 42 | 62 |
| Leavenworth | 1 | 3 | 6 | 6 | 6 | 7 |
| Wyandotte | 68 | 136 | 236 | 52 | 66 | 87 |
| Kansas subtotal | 77 | 164 | 294 | 88 | 114 | 156 |
| Area total | 228 | 448 | 790 | 174 | 231 | 320 |

[a] Negligible

Carbon monoxide and hydrocarbon emissions were considered to be nearly constant throughout the year, since most of these emissions are from mobile sources, industrial and commercial processes, refuse burning, and gasoline handling, which have little seasonal variation. The daily emission rates of these two pollutants are shown in Tables 37 and 38.

In Appendix E, emission densities in tons per day per square mile are listed for $SO_x$ and particulates on minimum, average, and maximum space-heating days for each of the emission zones in the study area (Table E-1). The listings for hydrocarbons and carbon monoxide are presented on an average-day basis. These data are plotted for areas of equal emission density by zone in Figures 16 through 23. The heavy emission density areas for these pollutants are located along the Missouri, Kansas, and Blue Rivers and in the highly populated and heavily traveled areas within the cities.

Table 37. EMISSIONS OF HYDROCARBONS AND CARBON MONOXIDE [BY SOURCE TYPE FOR AN AVERAGE DAY] IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966

| | HC | CO |
|---|---|---|
| Residential fuel | Neg[a] | 2 |
| Commercial and governmental fuel | 1 | 6 |
| Industrial fuel | Neg | 1 |
| Power plant fuel | Neg | 1 |
| Process emissions | 180 | -[b] |
| Motor vehicles | 320 | 1910 |
| Gasoline handling | 22 | -[b] |
| Railroads | 11 | 5 |
| Aircraft | 9 | 25 |
| Barges | 1 | Neg |
| Refuse burning | 94 | 88 |
| Area total | 630[c] | 2030[c] |

[a] Negligible.

[b] Assumed to be zero.

[c] Approximate values in significant figures.

Table 38. EMISSIONS OF HYDROCARBONS AND CARBON MONOXIDE BY COUNTY FOR AN AVERAGE DAY IN KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, SURVEY AREA, 1966 (tons/day)

| County | HC | CO |
|---|---|---|
| Cass | 21 | 65 |
| Clay | 44 | 130 |
| Jackson | 280 | 830 |
| Platte | 14 | 48 |
| Missouri subtotal | 359 | 1,073 |
| Johnson | 75 | 240 |
| Leavenworth | 21 | 93 |
| Wyandotte | 190 | 640 |
| Kansas subtotal | 286 | 973 |
| Area total | 645 | 2,046 |

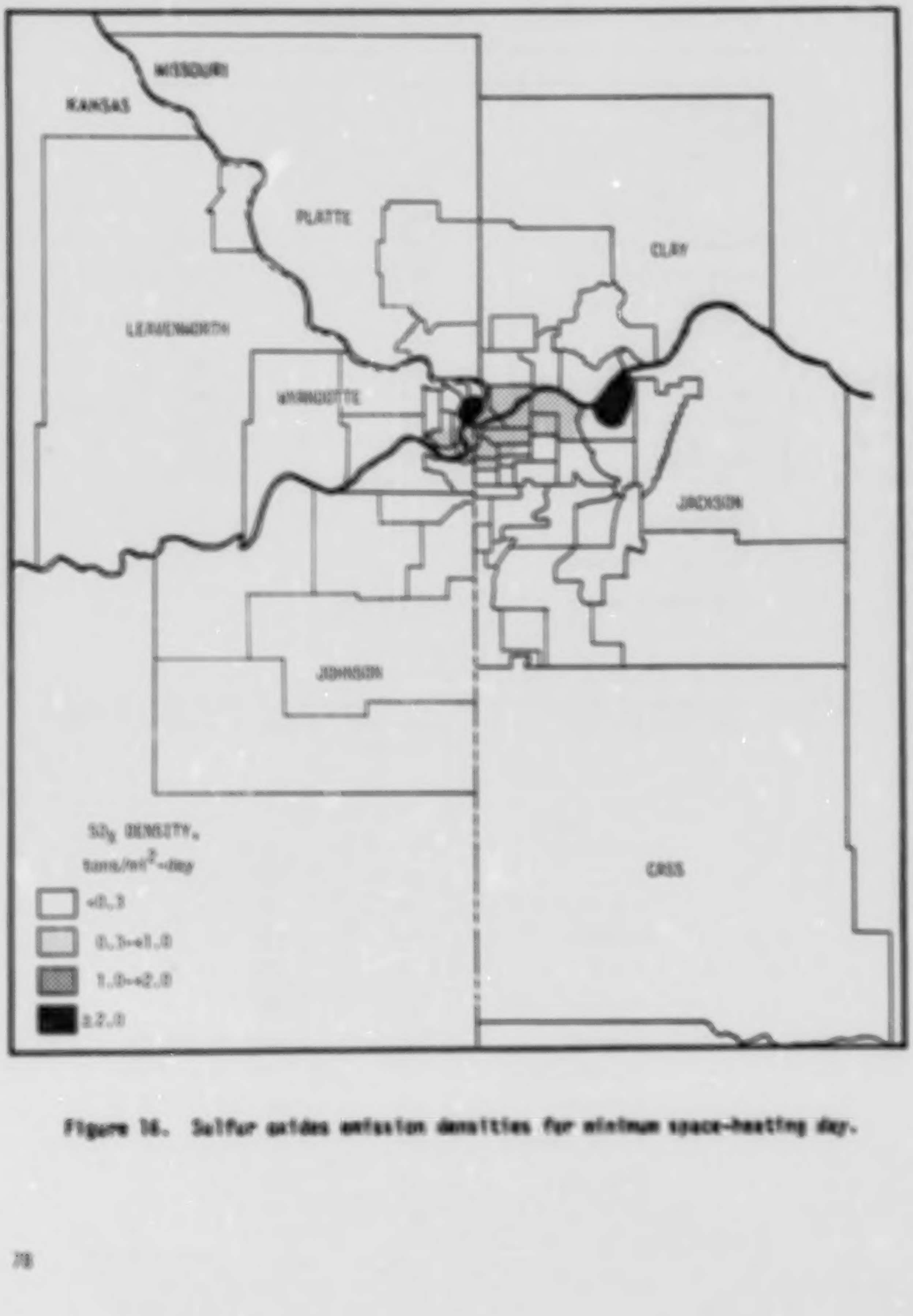

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
$SO_2$ DENSITY,
tons/mi$^2$-day
<0.3
0.3-<1.0
1.0-<2.0
≥2.0

Figure 16. Sulfur oxides emission densities for minimum space-heating day.

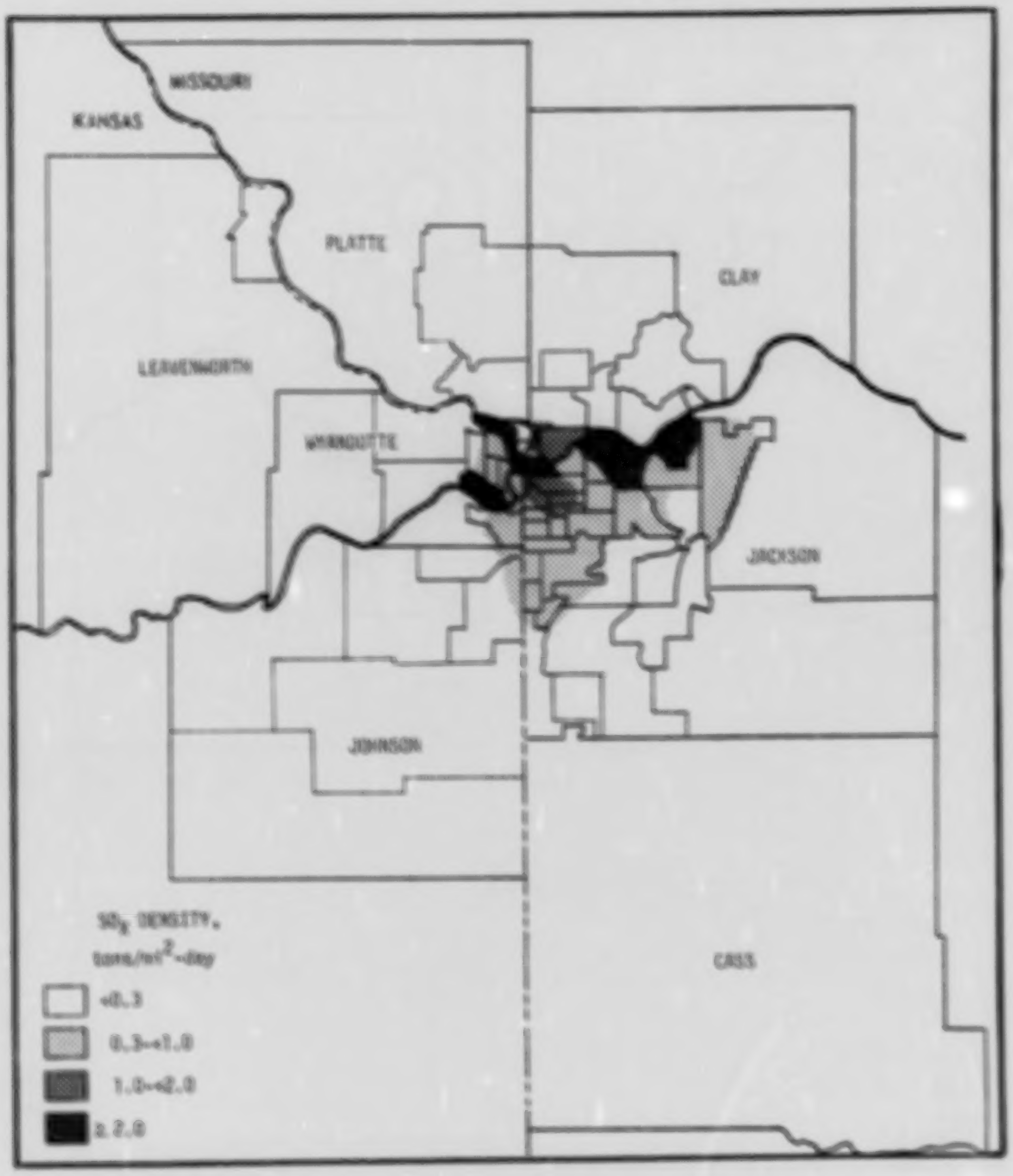

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
$SO_x$ DENSITY,
tons/mi$^2$-day
<0.3
0.3-<1.0
1.0-<2.0
≥ 2.0

Figure 17. Sulfur oxides emission densities for average space-heating day.

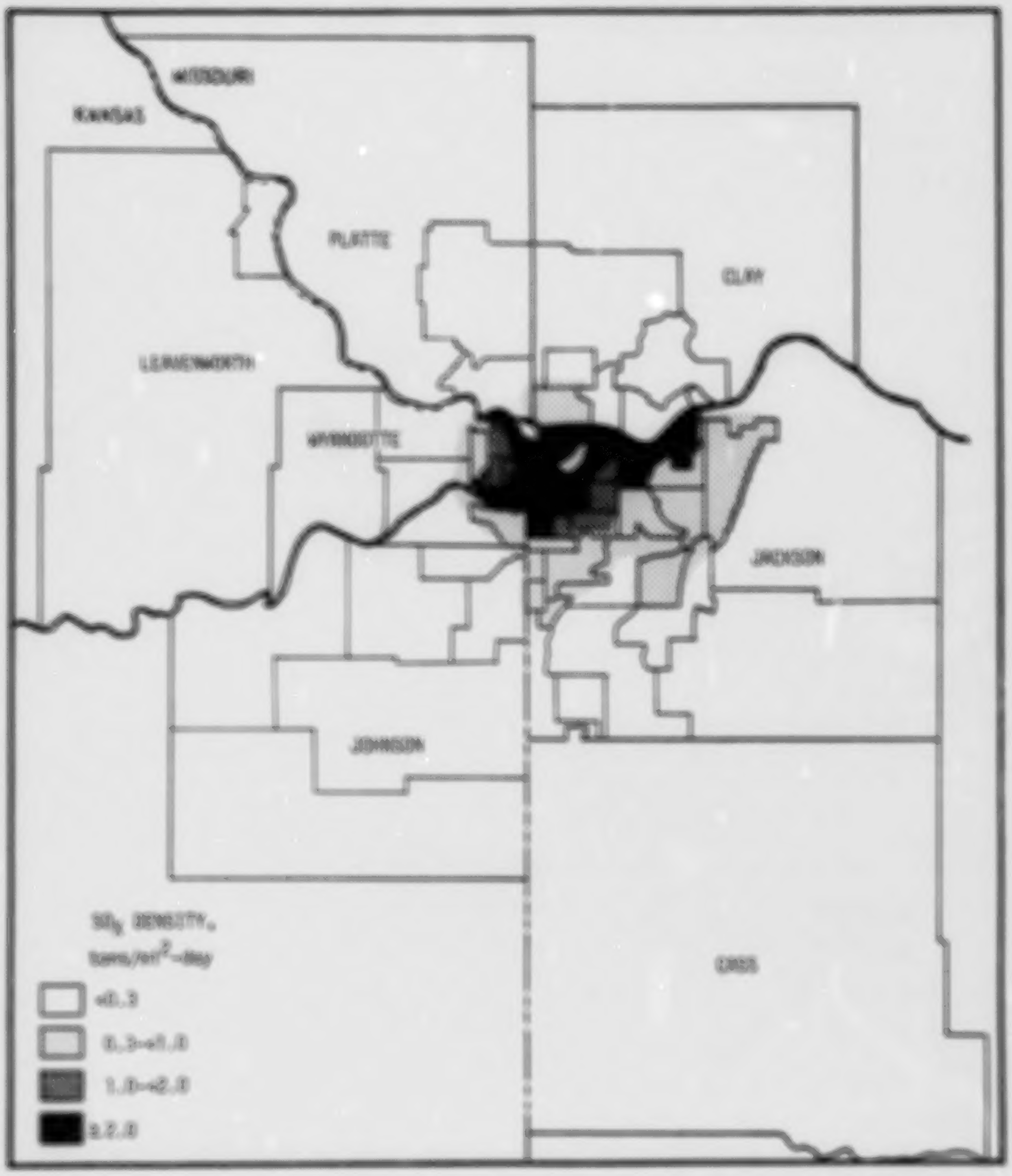

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
SO$_x$ DENSITY,
tons/mi$^2$-day
<0.3
0.3-<1.0
1.0-<2.0
≥2.0

Figure 18. Sulfur oxides emission densities for maximum space-heating day.

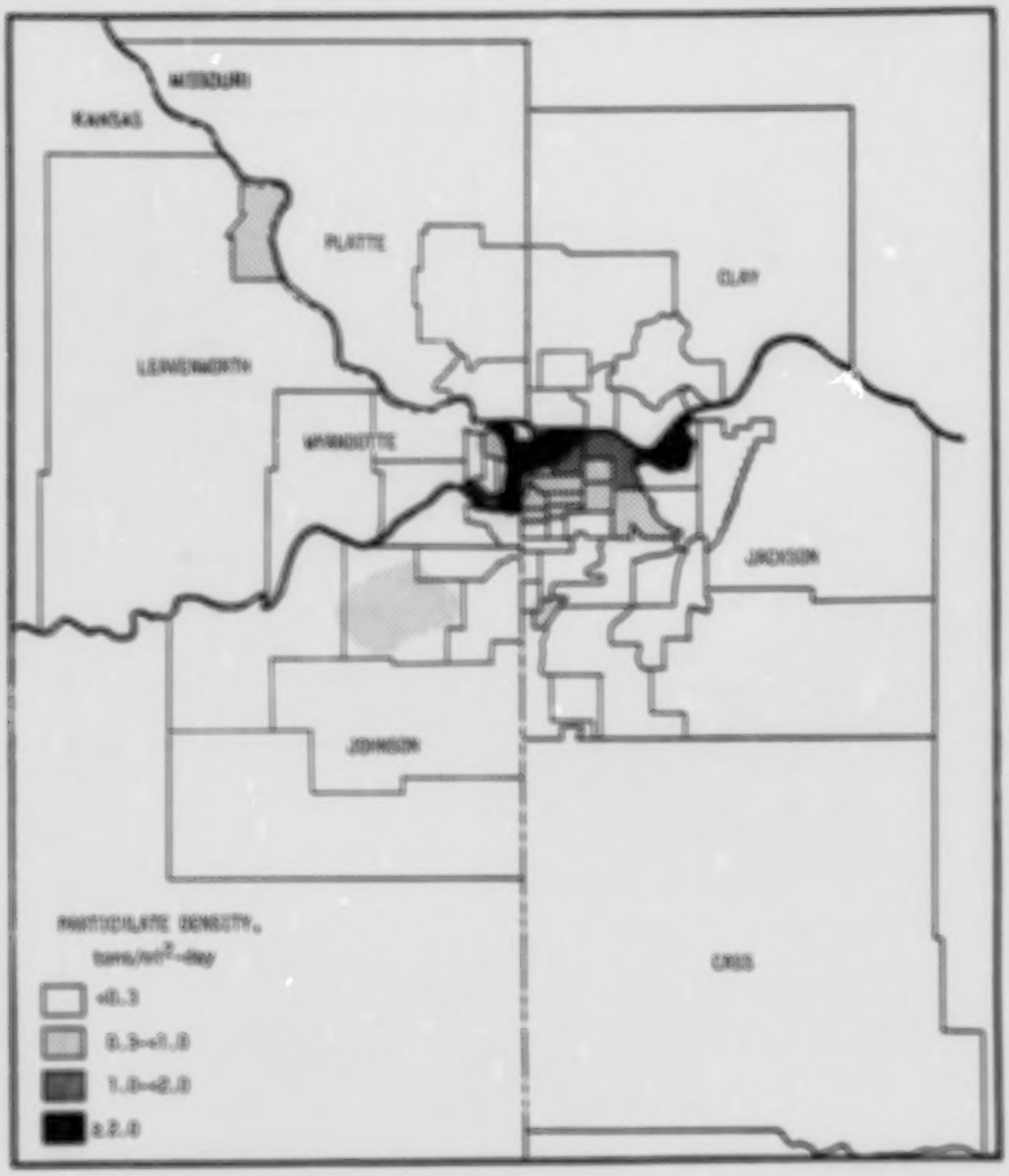

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
PARTICULATE DENSITY,
tons/mi$^2$-day
<0.3
0.3-<1.0
1.0-<2.0
≥2.0

Figure 19. Particulate emission densities for minimum space-heating day.

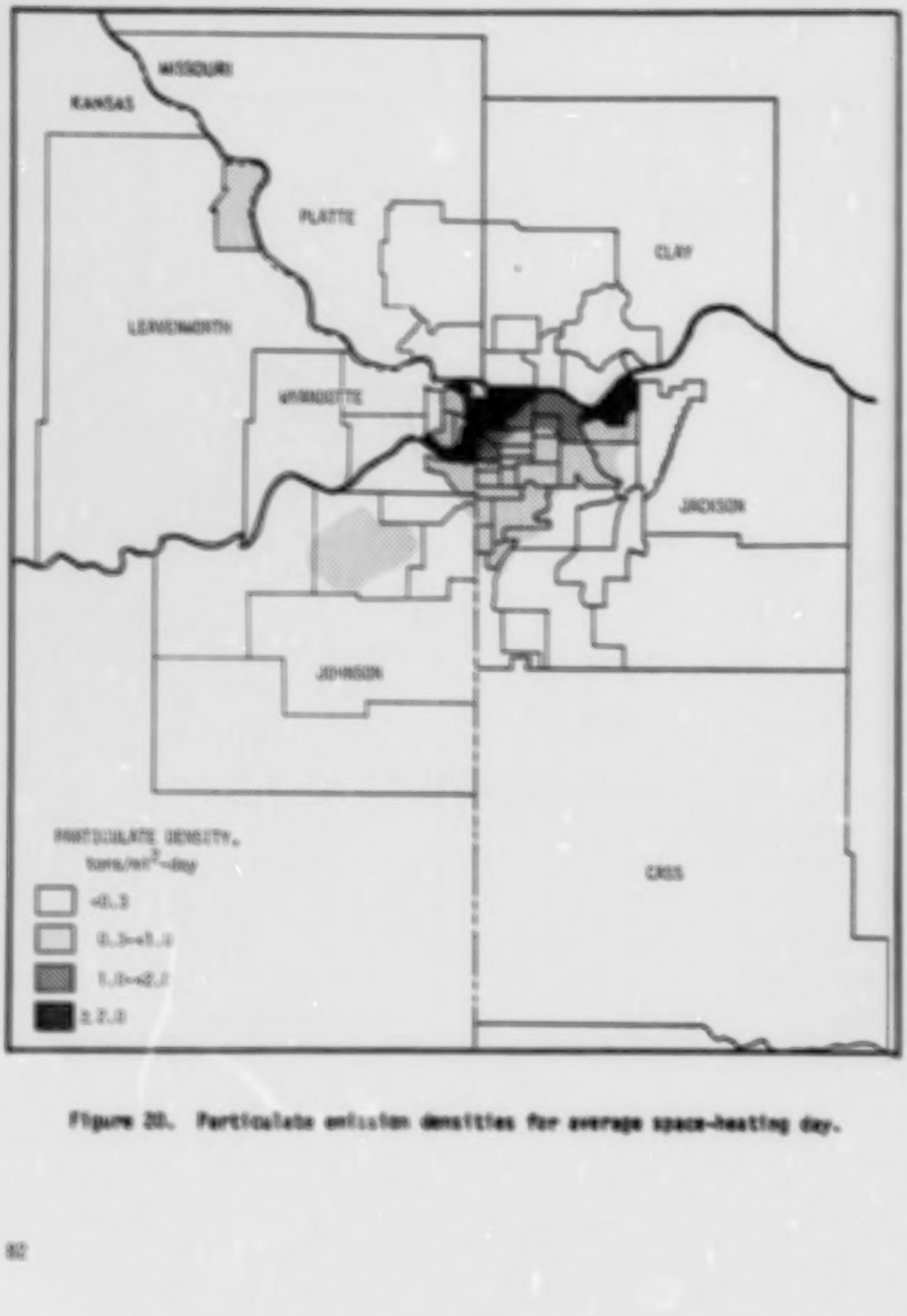

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
PARTICULATE DENSITY,
tons/mi$^2$-day
<0.3
0.3–<1.0
1.0–<2.0
≥ 2.0

Figure 20. Particulate emission densities for average space-heating day.

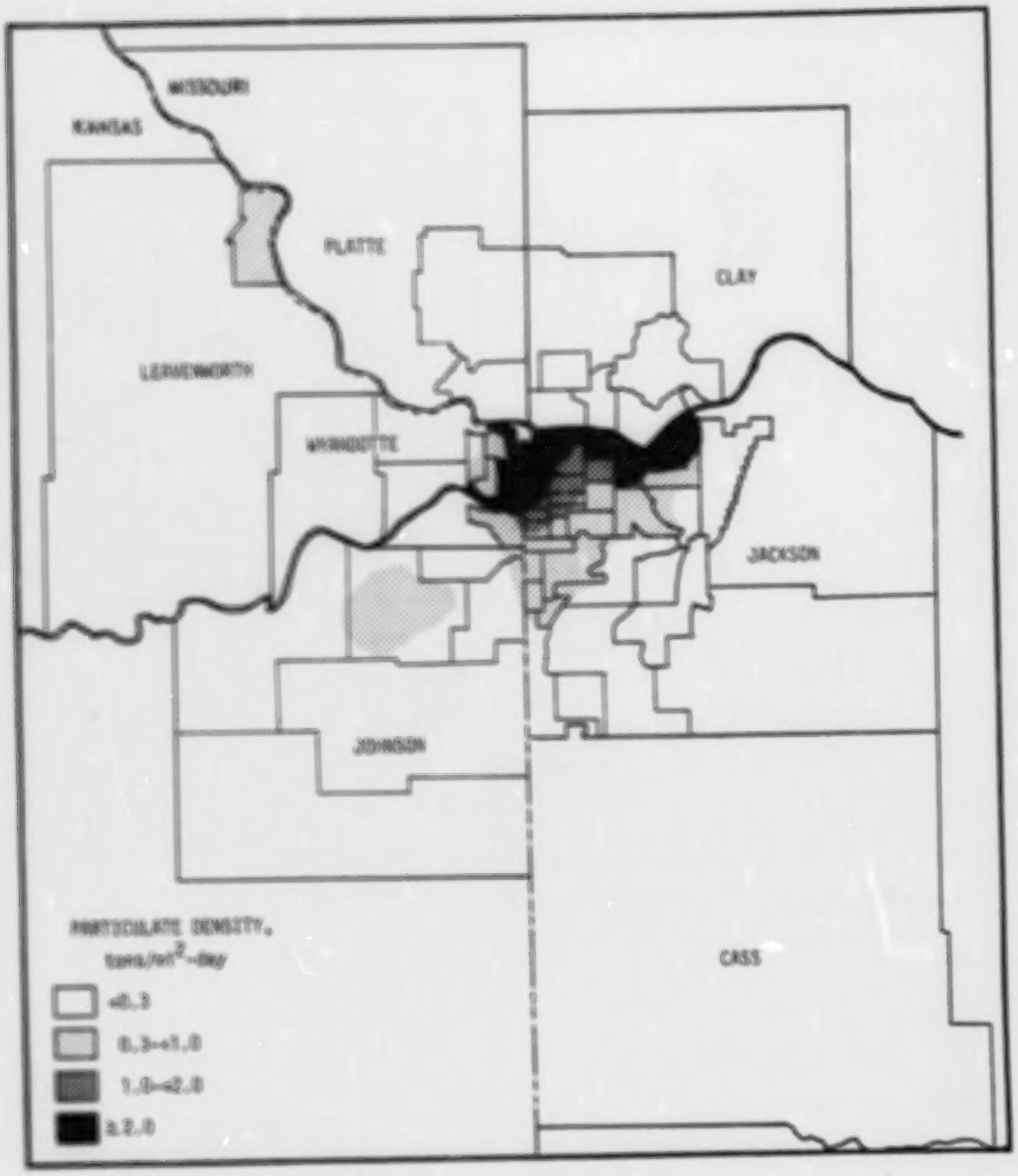

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
PARTICULATE DENSITY,
tons/mi²-day
<0.3
0.3-<1.0
1.0-<2.0
≥2.0

Figure 21. Particulate emission densities for maximum space-heating day.

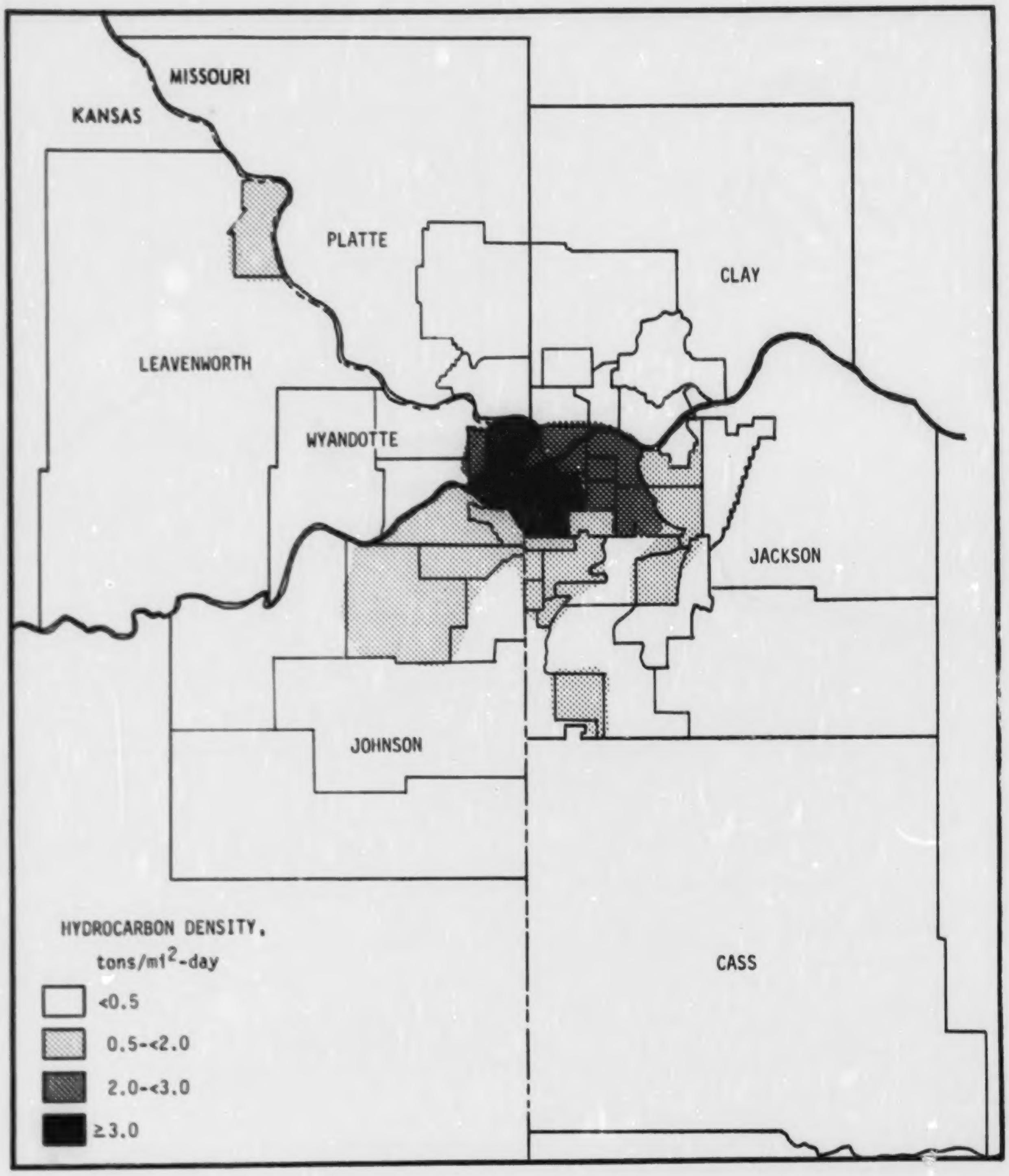

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
HYDROCARBON DENSITY,
tons/mi$^2$-day
<0.5
0.5-<2.0
2.0-<3.0
≥3.0

Figure 22. Hydrocarbon emission densities for an average day.

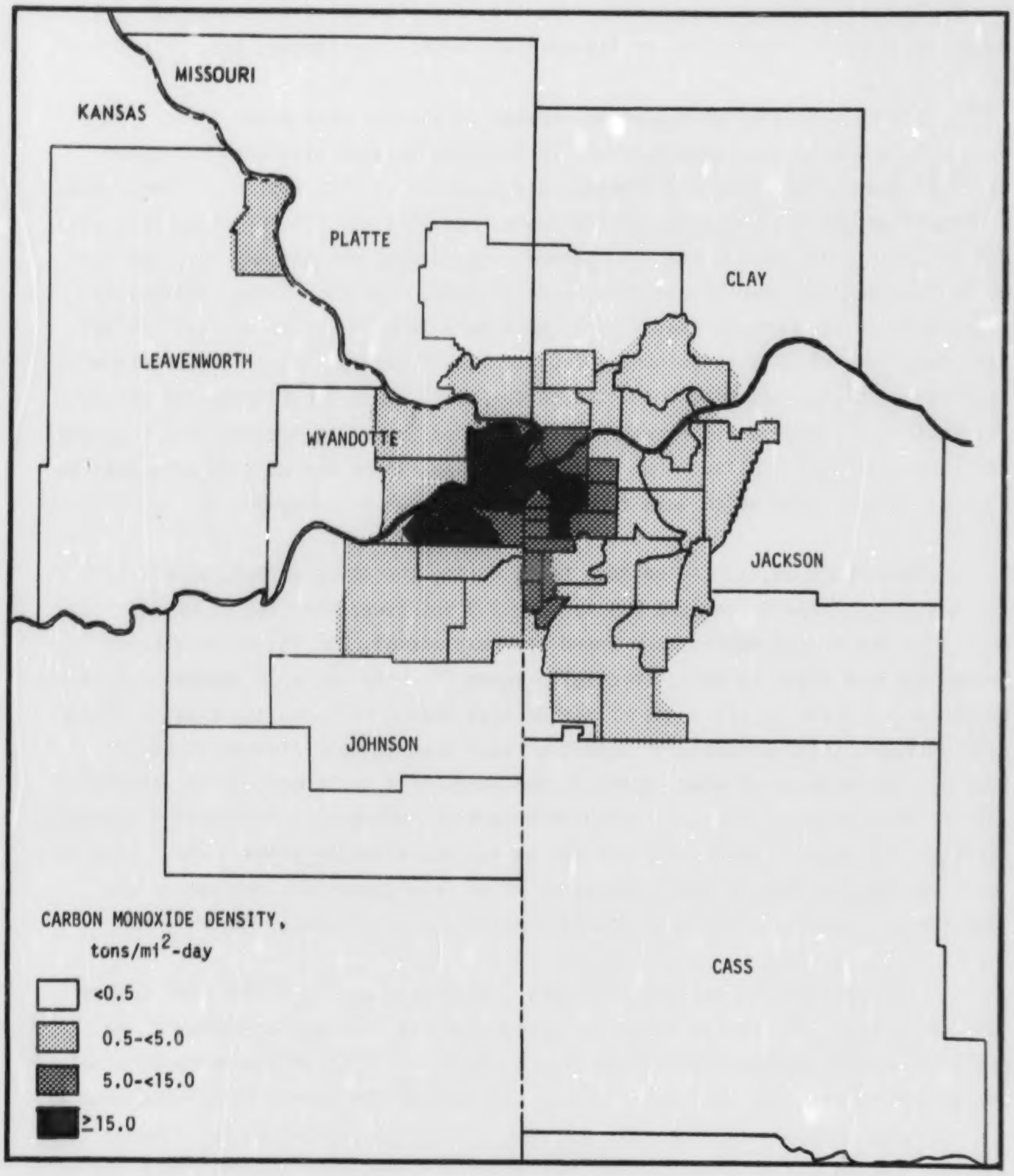

MISSOURI
KANSAS
PLATTE
CLAY
LEAVENWORTH
WYANDOTTE
JACKSON
JOHNSON
CASS
CARBON MONOXIDE DENSITY, tons/mi²-day
<0.5
0.5-<5.0
5.0-<15.0
≥15.0

Figure 23. Carbon monoxide emission densities for average day.

## METEOROLOGICAL DATA - REPRESENTATIVENESS OF SAMPLING PERIOD

For this study, the bulk of the aerometric and meteorological sampling was done in the period November 1966 through October 1967. During this period, meteorological observations of wind direction and wind speed were made at Municipal Airport, University of Missouri at Kansas City Campus, and Morse School.

The Municipal Airport station, located in the Missouri River Valley, is operated by the U.S. Weather Bureau. In addition to wind direction and speed, other standard meteorological elements are observed at this station. Also, long-period climatological records are available from this station for comparison with data collected during the sampling period. Any anomalies that may have occurred during the sampling period can thus be determined. The UMKC Campus station is located south of downtown Kansas City, well away from the river valleys. Since UMKC Campus is only 12 miles north of Grandview, Missouri, for which long-term records are available, data collected at the UMKC Campus can be compared with climatological information from Grandview. Morse School is located in the portion of the Kansas River Valley known as the Argentine; there are no long-term meteorological records with which data from this station can be compared.

From Table 39, it can be seen that, during the study period, wind speeds at the Municipal Airport averaged 9.4 mph, or 0.9 mph lower than the climatological norm. In the spring months, the speed was near normal, but it was well below normal for the other seasons, especially summer. There was a 70 percent increase in the occurrences of calms and of speeds less than 4 mph, and there was a 50 percent decrease in occurrences of speeds greater than 18 mph (Figures 24 and 5). However, occurrences of wind speeds in the range of 4 to 18 mph, which normally make up 85 percent of the wind speed observations, changed by less than 3 percent. Although the average wind speed for the period was slightly below normal, this was due to irregularities in the occurrences of extreme speeds and not due to any significant changes in the most commonly occurring wind speeds.

This decrease in average wind speed was also apparent at the UMKC Campus location. Here the average speed for the period was 8.1 mph, or nearly 2 mph below the climatological norm established at Grandview. Wind speed was nearest normal in the winter months, and well below normal the rest of the year. As was the case at the Municipal Airport station, the decrease was due to changes in the extreme values, that is, to an increase in occurrences of lower wind speeds, and a decrease in the higher speeds, rather than to differences in mid-range speeds (Figures 25 and 3). There were fewer calms recorded at the UMKC Campus than is normal for

Table 39. METEOROLOGICAL AVERAGES AND THEIR DEPARTURE FROM NORMAL DURING STUDY NOVEMBER 1966 - OCTOBER 1967

| | Winter (Dec-Feb) | Spring (Mar-May) | Summer (June-Aug) | Fall (Sept-Nov) | Annual |
|---|---|---|---|---|---|
| Municipal Airport average wind speed, mph | 9.5 | 11.2 | 8.0 | 9.0 | 9.4 |
| Departure from normal, mph | -0.6 | -0.2 | -1.8 | -0.9 | -0.9 |
| UMKC Campus average wind speed, mph | 9.1 | 9.3 | 6.0 | 7.8 | 8.1 |
| Departure from Grandview normal, mph | -1.1 | -2.1 | -2.3 | -2.0 | -1.8 |
| Morse School average wind speed, mph | 7.8 | 8.1 | 4.8 | 6.7 | 6.9 |
| Departure from Municipal Airport average, mph | -1.7 | -3.1 | -3.2 | -2.3 | -2.5 |
| Departure from normal number of cloudy days | +1 | +10 | +8 | +6 | +25 |
| Percent frequency of stability conditions | | | | | |
| Unstable | 12 | 12 | 31 | 15 | 17 |
| Departure from normal | +2 | -5 | -5 | -3 | -3 |
| Neutral | 55 | 67 | 36 | 50 | 52 |
| Departure from normal | +5 | +12 | +10 | +13 | +10 |
| Inversion | 33 | 22 | 33 | 35 | 31 |
| Departure from normal | -7 | -7 | -5 | -10 | -7 |
| Mean afternoon mixing depth, meters | 800 | 1450 | 1800 | 1300 | 1350 |
| Departure from normal, meters | 0 | -50 | +100 | -50 | 0 |
| Municipal Airport average temperatures, $^{o}F$ | 34.1 | 56.1 | 74.8 | 58.5 | 55.9 |
| Departure from normal, $^{o}F$ | -0.3 | +1.2 | -4.3 | -0.2 | -0.9 |
| Departure from normal number of degree-days | +6 | -131 | +14 | -90 | -201 |

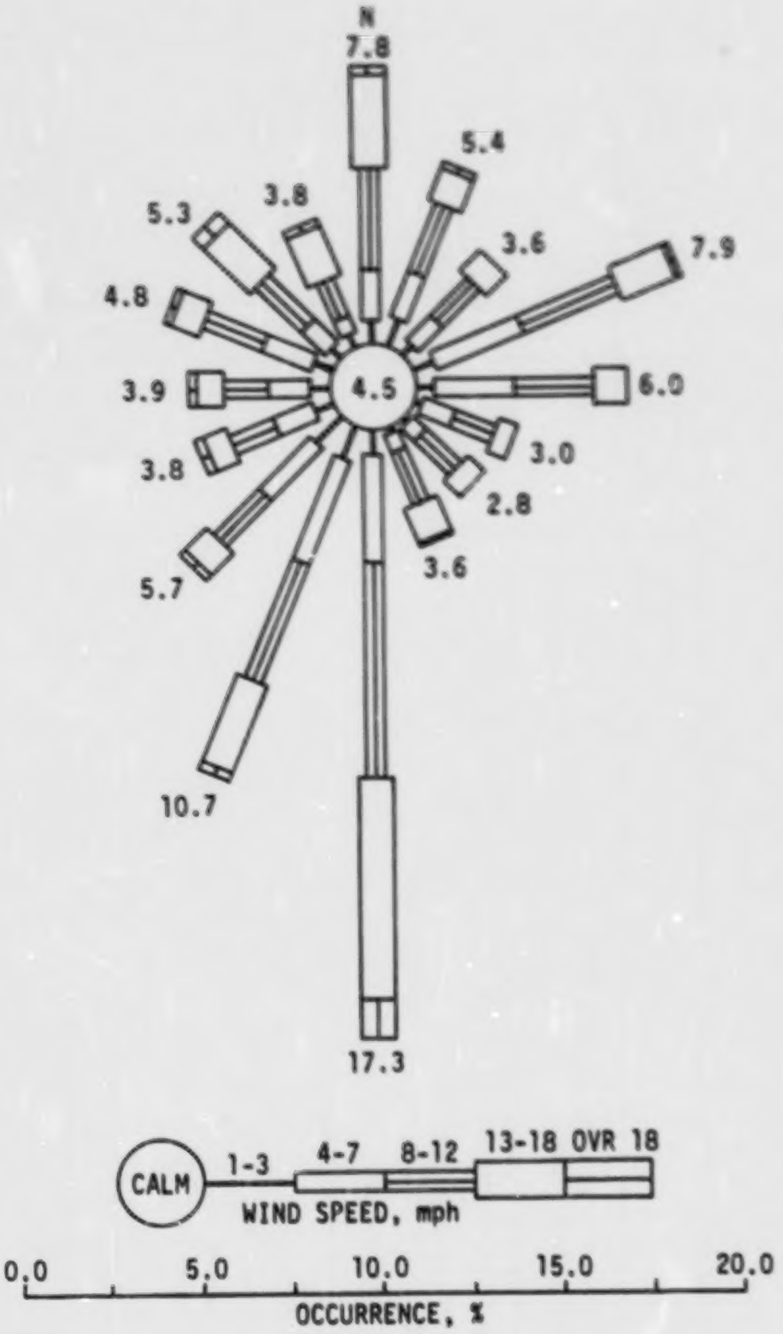


Figure 24. Wind rose for Municipal Airport, Kansas City, Missouri, November 1966 - October 1967.

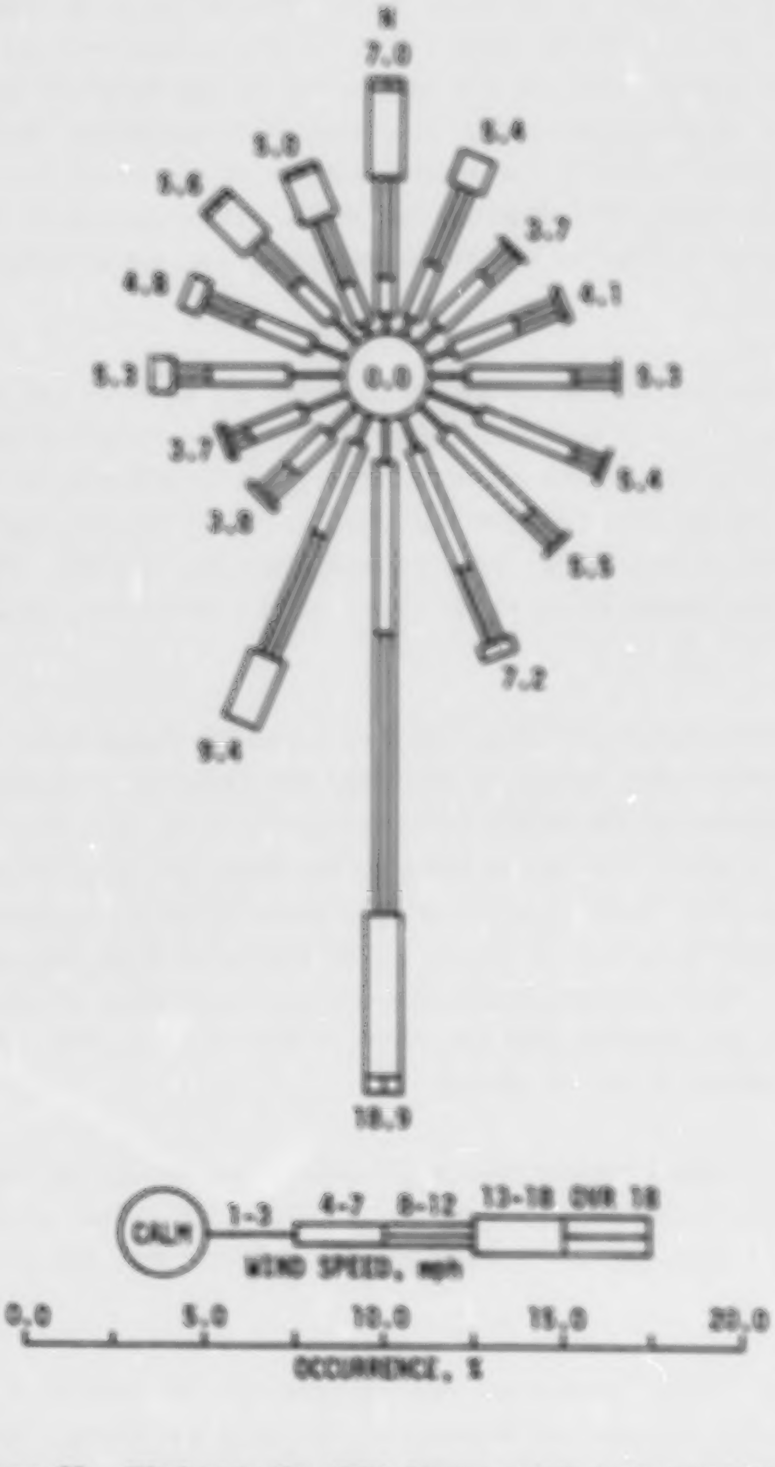


Figure 25. Wind rose for UMKC Campus, Kansas City, Missouri, November 1966 - October 1967.

Grandview because the wind instrument used at the former location was more sensitive to low wind speeds.

Average wind speeds at the Morse School location were the lowest observed in the Kansas City area during the study period. These speeds averaged 6.4 mph, or about 2.4 mph less than those for the same period at the Municipal Airport. Although the two locations are affected by similar topographies, the lower average speed at Morse School reflects the closer confines of the Kansas River Valley. Based on observations at the other two locations, it can reasonably be concluded that the average wind speed in the Morse School area was below normal during the study period.

The frequencies of wind directions observed at the Municipal Airport station during the study period (Figure 24) differ somewhat from normal (Figure 5). The most apparent difference is the definite increase in occurrences of southerly winds. Also, when the wind rose for UMKC Campus (Figure 25) is compared to the normal for Grandview (Figure 3), this increase again is apparent. Thus, there was an increase in the amount of southerly flow over the Kansas City area during the study period.

At the Morse School location, the wind direction frequencies (Figure 26) differed considerably from either of the other two locations. Channeling along the east-west orientation of the Kansas River Valley was quite apparent in the frequency of these directions. The valley walls to the north and south apparently restrict surface winds from northerly and southerly directions. Especially notable is the much smaller frequency of occurrence of southerly winds than occur at the other stations. The lower wind speeds and apparent channeling of winds at this location support the judgment that the river valleys in this area, although shallow, are pronounced enough to affect airflow.

Municipal Airport records show a definite increase over the normal amount of daytime cloudiness during the sampling period (Table 28). Only winter had a near-normal number of cloudy days; all other seasons had more than the normal number of cloudy days.

The Turner (1961)[4] method was used to determine the percent of time various classes of atmospheric stability occurred at the Municipal Airport during the study period (Table 29). Throughout the sampling period the number of unstable and inversion conditions were fewer and the number of neutral stability conditions were

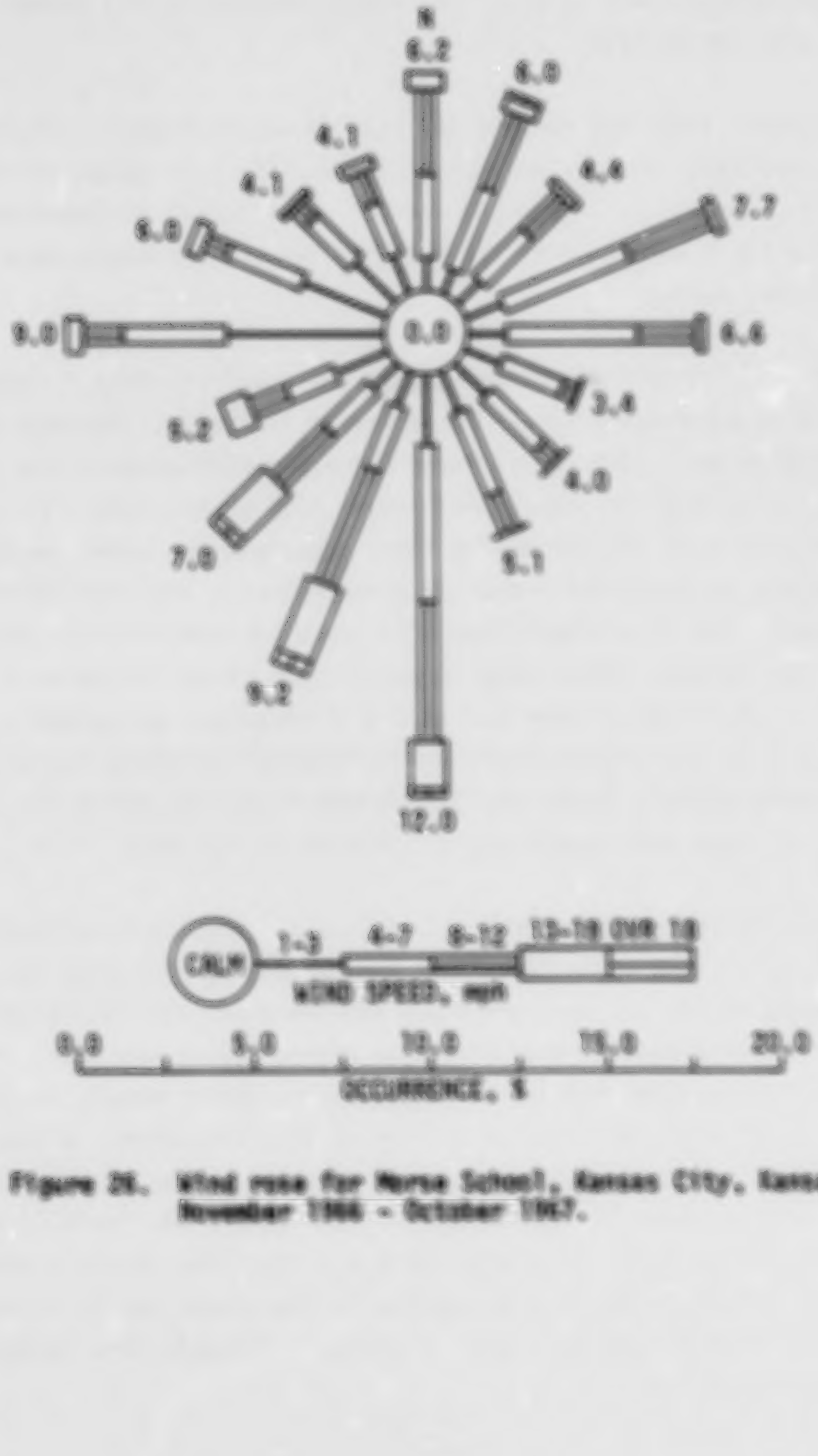


Figure 26. Wind rose for Morse School, Kansas City, Kansas, November 1986 - October 1987.

greater than normal. Neutral stability usually occurs during cloudy and/or windy conditions. Since the wind-speed analysis indicated a lower-than-normal frequency of strong winds, the increase in neutral stability can be attributed to the general increase in cloudiness during the sampling period.

Available data from Columbia, Missouri (Table 38), indicate that mean afternoon mixing depths were about normal. The slight departures from normal mixing depths varied with the seasons.

Temperatures (Table 39) for the sampling period as a whole were about 1° below normal. The fall, winter, and spring months were near normal or slightly above normal; the summer was 4.3° below normal. As a result of temperatures being near or slightly above normal during the heating season, the degree-days were slightly fewer than normal.

The temperatures and degree-days during the sampling period indicate that requirements for space-heating during three heating seasons of the year were near or slightly below normal. Therefore, other non-space-heating emissions being constant, it is concluded that near normal amounts of particulates and sulfur dioxide were emitted into the air during these seasons. The summer months were cooler than normal; although the number of establishments with air-conditioning may have increased, the power requirements for each air-conditioning plant were probably less than normal. Since natural gas is used almost exclusively in utility power stations at this time of year and pollutant emissions are normally small, there probably was no significant departure from normal emissions during the summer. Therefore, sulfur dioxide and particulate emissions during the study period should have been near normal for all seasons of the year.

Because of increases in neutral stability and decreases in unstable and inversion cases during the study period, the dispersive capability of the atmosphere decreased somewhat during the daylight hours and increased in the nighttime hours. Vertical mixing as indicated by mean afternoon mixing depths was near normal. Since wind speed during the study period was slightly below normal, this contributed to a small decrease in the dilution ability of the atmosphere. Although certain conditions during the sampling period enhanced dispersion, and others suppressed it, as a whole, conditions were near normal during the study. The increase in southerly winds throughout the Kansas City area indicates that more than the normal amount of pollutants should have been carried northward; therefore, locations north of major sources of pollution may have experienced more frequent than normal air contamination during the study.

# III. POLLUTION IMPACT ON THE STUDY AREA

## POLLUTION ROSES

Pollution roses were constructed for the four continuous sampling sites in the Kansas City area. These are "source identification" roses; they indicate the percent of the occurrences of each wind direction accompanied by pollution concentrations greater than some selected level. Thus, if for a notable portion of its occurrences, a given wind direction is associated with a significant pollutant level, then it is probable that there is a source of that pollutant in the upwind direction.

### Sulfur Dioxide Pollution Roses

As a supplement to the actual measurements of sulfur dioxide, theoretical diffusion models[13] were used to calculate short-period pollutant concentrations. The ground-level centerline $SO_2$ concentrations that each of the identified major sources of this pollutant can deliver to each sampling site, calculated for wintertime emissions rates, are given in Table 40. These results assist in identifying specific pollutant sources indicated by the $SO_2$ pollution roses. During the other three seasons of the year, the concentrations caused by most combustion sources would be about one-fourth to one-half those listed in Table 40. Process source emissions would not vary with the seasons.

Sulfur dioxide pollution roses for the Waterworks station show a definite seasonal variation. Figures 27 and 28 are roses for $SO_2$ concentrations greater than 0.05 ppm. During the winter months 0.05 ppm was exceeded in 7 percent of the $SO_2$ samples; during the rest of the study this level was exceeded in only 2.5 percent of the samples. The winter pollution rose (Figure 27) indicates that winds from the northeast, from the east through east-southeast, and from the south-southwest accompanied 8, 30, and 23 percent, respectively, of all concentrations greater than 0.05 ppm that occurred during the winter measurement period. During the other seasons of the year easterly winds were infrequently associated with concentrations exceeding 0.05 ppm. The south-southwesterly direction, though, accompanied 70 percent of all occurrences greater than 0.05 ppm during the other seasons. The seasonal variation in the direction of $SO_2$ source areas indicates the following:

# Table 40. CALCULATED GROUND-LEVEL CENTERLINE SULFUR DIOXIDE CONCENTRATIONS FROM SINGLE SOURCES FOR WIND SPEED OF 4 METERS PER SECOND AND FOR A TIME INTERVAL OF ABOUT 10 MINUTES

(parts per million)

| Source | Waterworks | | | Police Garage | | | UMKC Campus | | | Norton School | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unstable | Neutral | Inversion | Unstable | Neutral | Inversion | Unstable | Neutral | Inversion | Unstable | Neutral | Inversion |
| Sibley Power Plant | -[a] | 0.04 | 0.10 | - | 0.03 | 0.16 | - | 0.03 | 0.17 | - | 0.03 | 0.16 |
| Cameron Power Plant | - | - | 0.07 | - | - | 0.07 | - | 0.41 | 0.08 | - | - | 0.08 |
| Grand Avenue Power Plant | - | 0.15 | 0.04 | 0.11 | 0.07 | - | - | 0.07 | 0.07 | - | 0.11 | 0.04 |
| Hawthorne Power Plant | 0.03 | 0.24 | 0.03 | 0.03 | 0.24 | 0.03 | 0.03 | 0.19 | 0.07 | 0.04 | 0.19 | 0.07 |
| Quindaro Power Plant | 0.03 | 0.24 | 0.03 | - | 0.15 | 0.06 | - | 0.09 | 0.09 | - | 0.15 | 0.09 |
| Kaw Power Plant | 0.02 | 0.14 | 0.10 | 0.02 | 0.22 | 0.06 | - | 0.16 | 0.08 | 0.30 | 0.08 | - |
| Blue Valley Power Plant | - | 0.02 | 0.05 | - | 0.02 | 0.05 | 0.02 | 0.02 | 0.05 | - | 0.02 | 0.04 |
| Hercules Sunflower | - | - | 0.05 | - | - | 0.05 | - | - | 0.05 | - | - | 0.06 |
| Lake City Arsenal | - | - | 0.03 | - | - | 0.03 | - | - | 0.03 | - | - | 0.02 |
| Corn Products | - | 0.05 | 0.13 | - | 0.06 | 0.14 | - | - | 0.05 | - | 0.02 | 0.02 |
| Chemagro | - | - | 0.06 | - | - | 0.07 | - | - | 0.04 | - | 0.03 | 0.03 |
| Phillips Petro (combustion) | 0.02 | 0.17 | 0.28 | - | 0.11 | 0.27 | - | 0.02 | 0.15 | - | 0.06 | 0.22 |
| Phillips Petro (process) | 0.07 | 0.59 | 0.26 | 0.08 | 0.46 | 0.36 | 0.03 | 0.10 | 0.40 | 0.03 | 0.26 | 0.43 |
| American Oil (combustion) | - | - | 0.06 | - | - | 0.07 | - | - | 0.05 | - | - | 0.05 |
| American Oil (process) | 0.02 | 0.04 | - | 0.02 | 0.04 | - | 0.02 | 0.04 | - | 0.02 | 0.02 | - |

---

[a] Dash indicates a concentration of less than 0.02 ppm.

1. The effect of several large power plants located to the east along the Missouri River was significant during the winter, when large quantities of $SO_2$ were emitted.
2. During the entire year, about equal frequencies of $SO_2$ concentrations greater than 0.05 ppm occur when the wind is from the south-southwest, the direction of the Phillips Petroleum refinery; this indicates interstate transport of pollution.
3. The southerly and southwesterly pollution rose arms, which give a stronger indication of $SO_2$ sources during the winter than during the rest of the year, indicate the directions of the Grand Avenue and Kaw Power Plants, respectively.

The arm to the northeast on the winter pollution rose is not associated with any individual major source of $SO_2$ identified in the survey; many small, local sources situated to the northeast apparently contribute to the $SO_2$ level.

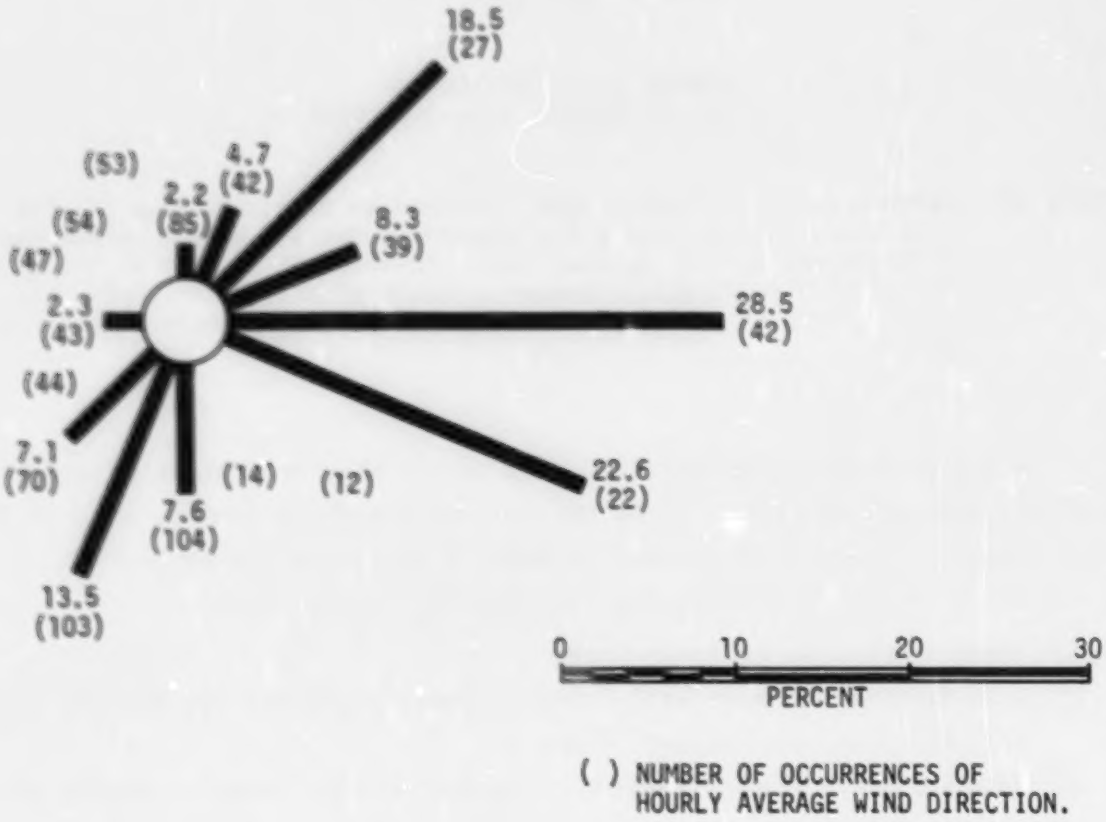


Figure 27. Waterworks $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.05 ppm during the period December 1966 through February 1967. Meteorological data is from the Municipal Airport site. Number of hours of pollutant sampling is 860. Hours of pollutant sampling with missing meteorological data is 39.

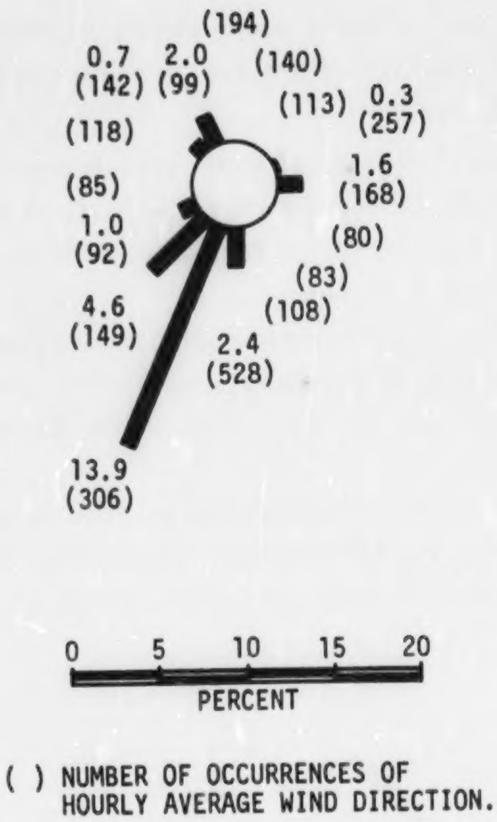


**Figure 28.** Waterworks $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.05 ppm during the period March through October 1967. Meteorological data is from the Municipal Airport site. Number of hours of pollutant sampling is 2776. Hours of pollutant sampling with missing meteorological data is 114.

The $SO_2$ pollution roses for the Police Garage station (Figures 29 and 30) also show a seasonal variation. From the rose for the winter months, which is for concentrations exceeding 0.05 ppm and includes 15 percent of the sampled $SO_2$ concentrations, it is possible to identify four $SO_2$ source areas:

1. North - Grand Avenue Power Plant.
2. East-northeast through east - several power plants and the American Oil refinery along the Missouri River.
3. East-southeast through southeast - several process emission sources along the Blue River.
4. West-southwest through west - Kaw Power Plant.

The wind directions represented by the three areas first listed above were each responsible for about 8 percent of the occurrences of concentrations greater than 0.05 ppm; the direction for the fourth area accounted for about 17 percent of such concentrations. Winds from the north-northwest through northwest, the direction of the Phillips Petroleum refinery accompanied only 7 percent of the concentrations being considered. However, during the rest of the year, when only 2 percent of the sampled $SO_2$ concentrations were greater than 0.05 ppm, northwesterly wind directions were frequently accompanied by the specified $SO_2$ concentrations. Winds from these directions accompanied 37 percent of the $SO_2$ concentrations greater than 0.05 ppm, whereas winds from the direction of the Kaw Power Plant accompanied only 2 percent. The importance of power plants in the winter, and of $SO_2$ process emissions the rest of the year, again is evident. It should be noted that when emissions from either the Kaw Power Plant or Phillips Petroleum refinery affect this location, the interstate transport of air pollutants occurs.

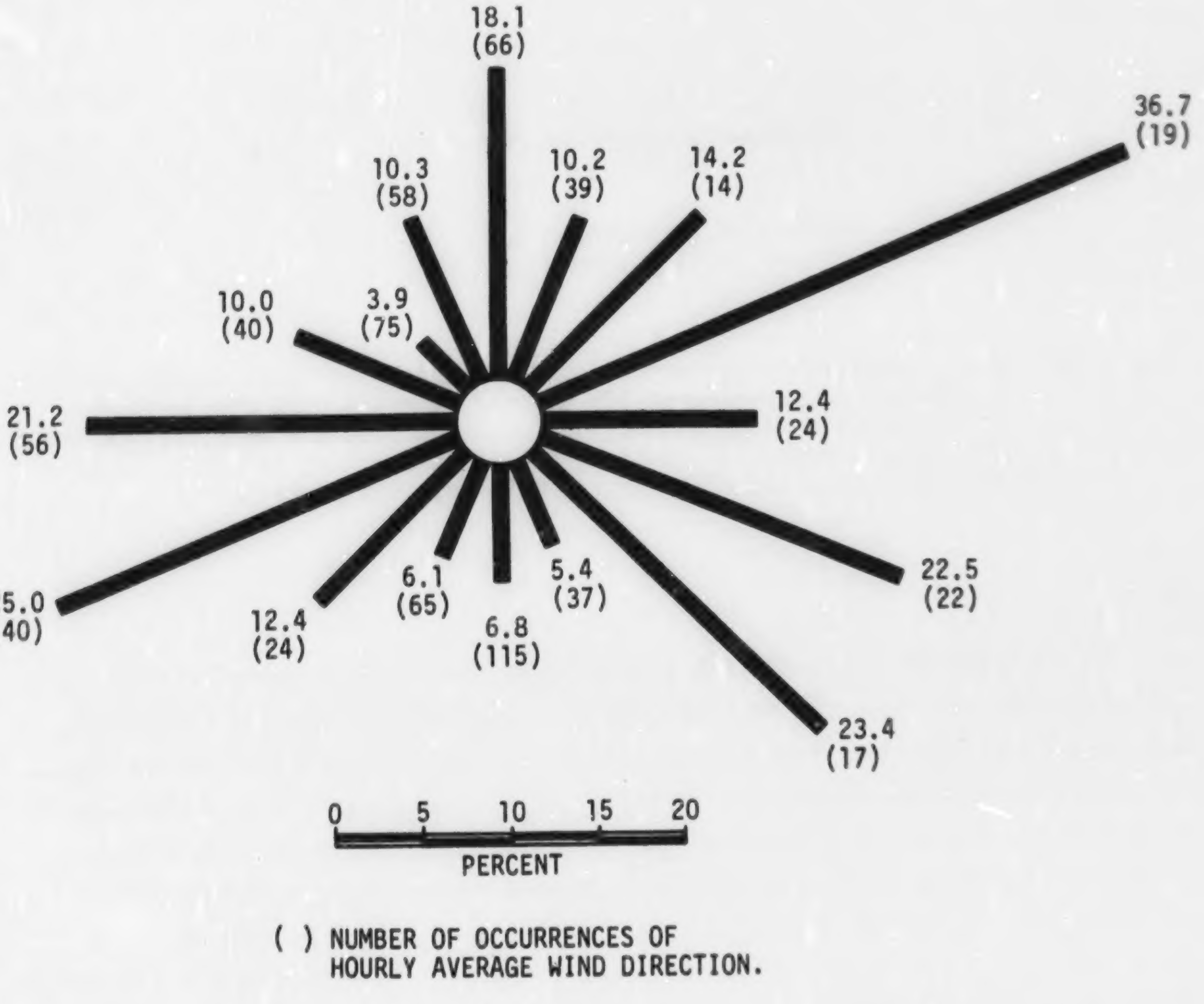


Figure 29. Police Garage $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.05 ppm during the period December 1966 through February 1967. Meteorological data is from the UMKC site. Number of hours of pollutant sampling is 854. Hours of pollutant sampling with missing meteorological data is 143.

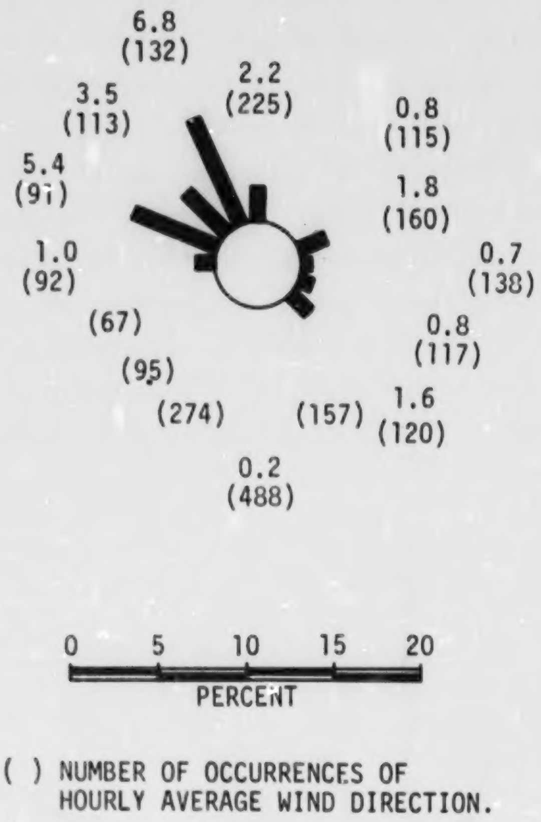


Figure 30. Police Garage $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.05 ppm during the period March through October 1967. Meteorological data is from the UMKC site. Number of hours of pollutant sampling is 2784. Hours of pollutant sampling with missing meteorological data is 257.

The wintertime $SO_2$ pollution rose (Figure 31) for UMKC Campus station shows levels greater than 0.02 ppm and includes 4 percent of this station's $SO_2$ data. This rose shows that the wind direction most frequently accompanied by the selected $SO_2$ levels is west-northwest, the direction of the Kaw Power Plant. This wind direction accompanied 20 percent of the concentrations greater than 0.02 ppm. Winds from the directions northeast through east-northeast were infrequently associated with 0.02 ppm or more $SO_2$, and accompanied only 3 percent of these concentrations. During the spring and summer months, winds from the northeasterly directions were more important (Figure 32) because they accompanied 37 percent of the selected $SO_2$ concentrations, compared to only 2 percent for west-northwest. During these months, 0.02 ppm was exceeded by 2.5 percent of the samples. The pollution roses indicate that, during the winter, interstate transport from the

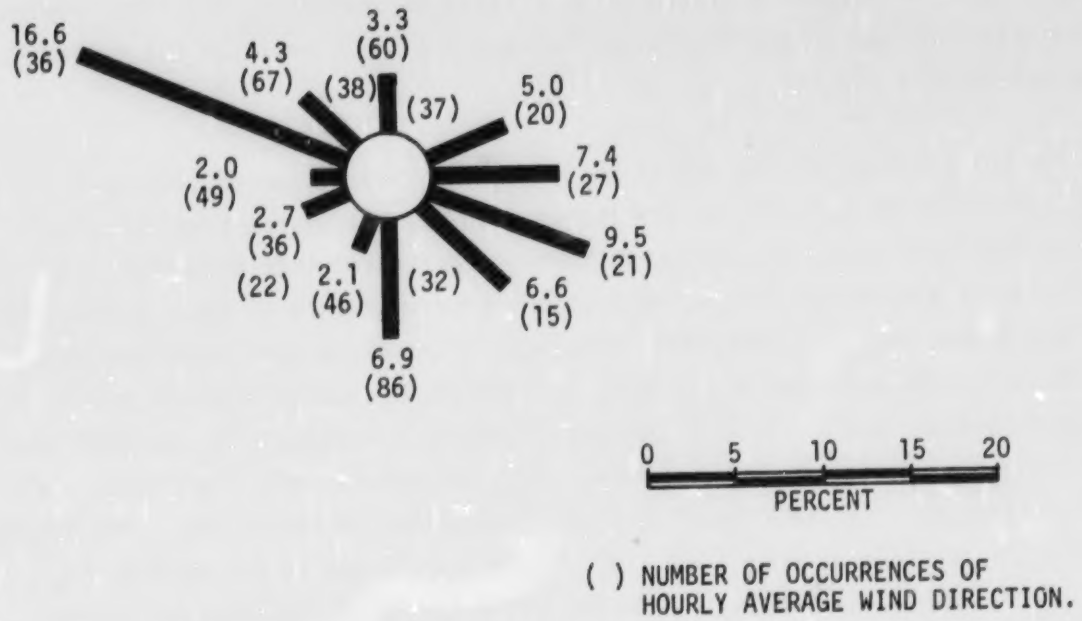


Figure 31. UMKC $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.02 ppm during the period December 1966 through February 1967. Meteorological data is from the UMKC site. Number of hours of pollutant sampling is 708. Hours of pollutant sampling with missing meteorological data is 99.

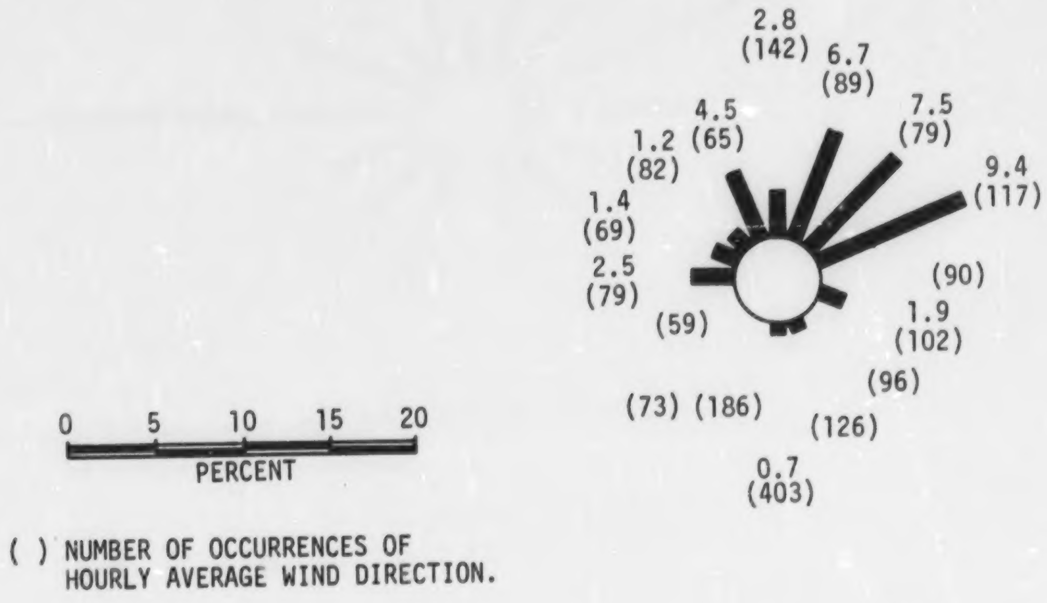


Figure 32. UMKC $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.02 ppm during the period March through July 1967. Meteorological data is from the UMKC site. Number of hours of pollutant sampling is 2028. Hours of pollutant sampling with missing meteorological data is 171.

Kaw Power Plant has a notable effect on this location and during the other months, the industrial sources in the Blue River Valley, including American Oil refinery, are the predominate sources.

The Morse School winter season $SO_2$ pollution rose (Figure 33) is for concentrations exceeding 0.02 ppm and includes 15 percent of the sampled concentrations. When east and west-northwest through northwest winds occurred, they were frequently associated with concentrations greater than 0.02 ppm. During the spring and summer months (Figure 34), the latter directions were less frequently associated with the selected $SO_2$ levels. In the winter, winds from the northwesterly directions accompanied 18 percent of the occurrences of $SO_2$ greater than 0.02 ppm; whereas during the other months, they accompanied only 7 percent. This variation indicates the Kaw Power Plant as a wintertime source of $SO_2$. The source located to the east is unidentified. During the spring and summer months, $SO_2$ moving up the Kansas River Valley from the direction of the Phillips Petroleum refinery is apparently reflected in the northeasterly arm of the pollution rose.

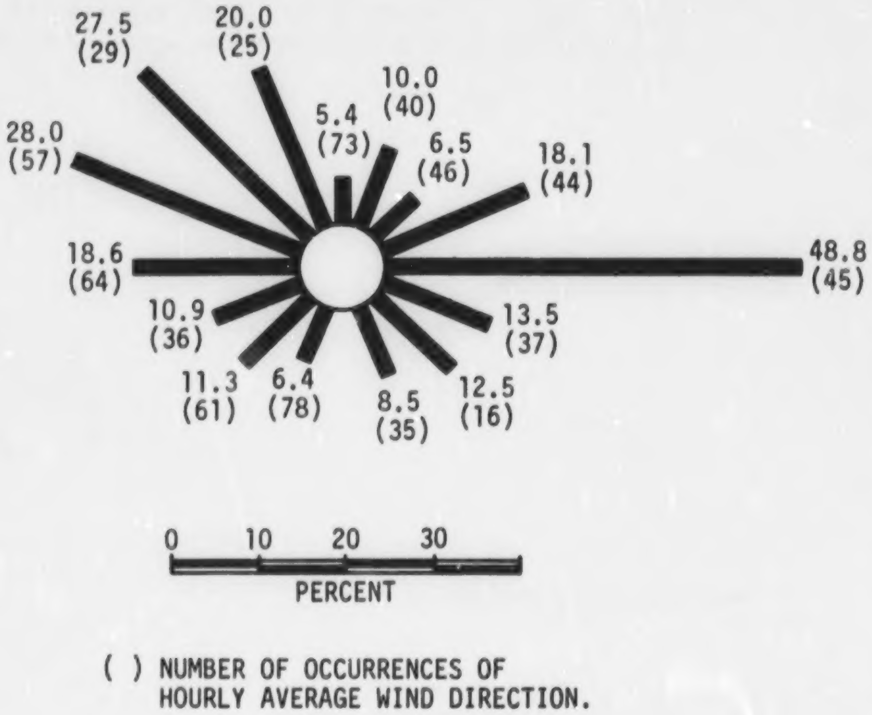


Figure 33. Morse School $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.02 ppm during the period December 1966 through February 1967. Meteorological data is from the Morse School site. Number of hours of pollutant sampling is 900. Hours of pollutant sampling with missing meteorological data is 154.

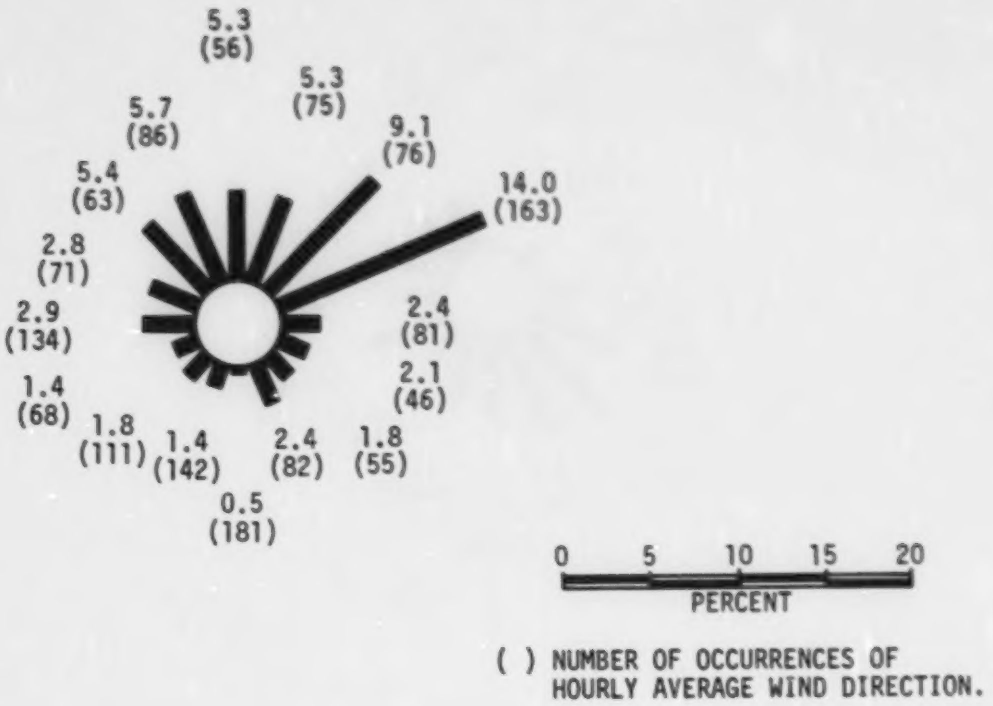


Figure 34. Morse School $SO_2$ pollution rose. Percentage of occurrences of wind directions accompanied by $SO_2$ concentrations > 0.02 ppm during the period March through July 1967. Meteorological data is from the Morse School site. Number of hours of pollutant sampling is 1976. Hours of pollutant sampling with missing meteorological data is 486.

Soiling Index Pollution Roses

Particulate soiling index pollution roses were constructed for four sampling locations. At these locations, there was no significant variation in the pollution roses with season. The roses for all locations except Morse School are for soiling index values exceeding 0.9 Coh; the Morse School rose is for values greater than 1.9 Coh.

The soiling index pollution rose for the Waterworks station (Figure 35), which includes 5 percent of all soiling index data for the station, indicates that all wind directions except west through north are accompanied by soiling index values greater than 0.9 Coh 3 percent or more of the time. South through southwest are the most significant of these wind directions since they are accompanied by 40 percent of the soiling index values greater than 0.9 Coh. This indicates areas in the directions of North Kansas City and in the Kansas River Valley as locations of sources from which these soiling particulates originate.

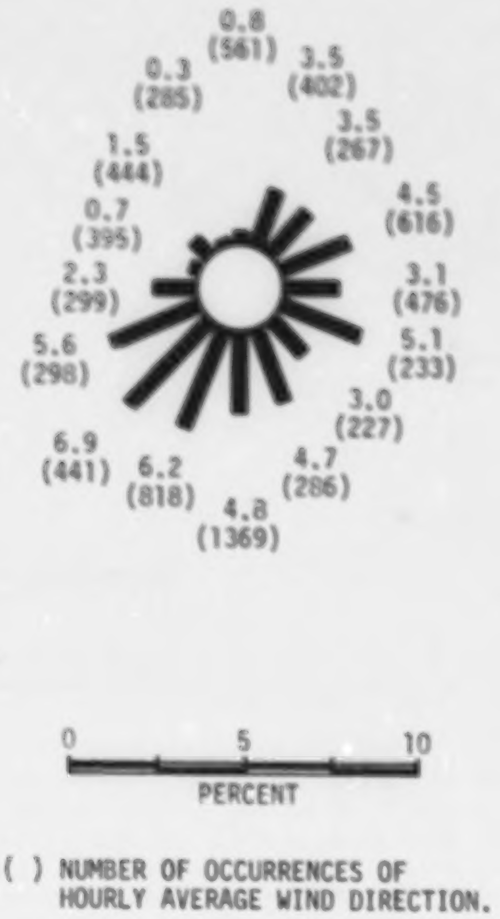


Figure 35. Waterworks soiling index pollution rose. Percentage of occurrences of wind directions accompanied by Coh values > 0.9 during the period November 1966 through October 1967. Meteorological data is from the Municipal Airport site. Number of hours of pollutant sampling is 7756. Hours of pollutant sampling with missing meteorological data is 337.

Nine percent of the soiling index values for the Police Garage are greater than 0.9 Coh and are included in its pollution rose (Figure 36). This rose shows west-southwest through west-northwest and northeast through east-southeast as wind directions frequently accompanied by soiling index values greater than 0.9 Coh. These are the general directions of the Kansas River and the Blue River Valley industrial complexes. Several open-burning operations along the Missouri River are in a northeasterly direction from the station. These source areas produced a total of 40 percent of the soiling index values greater than 0.9 Coh.

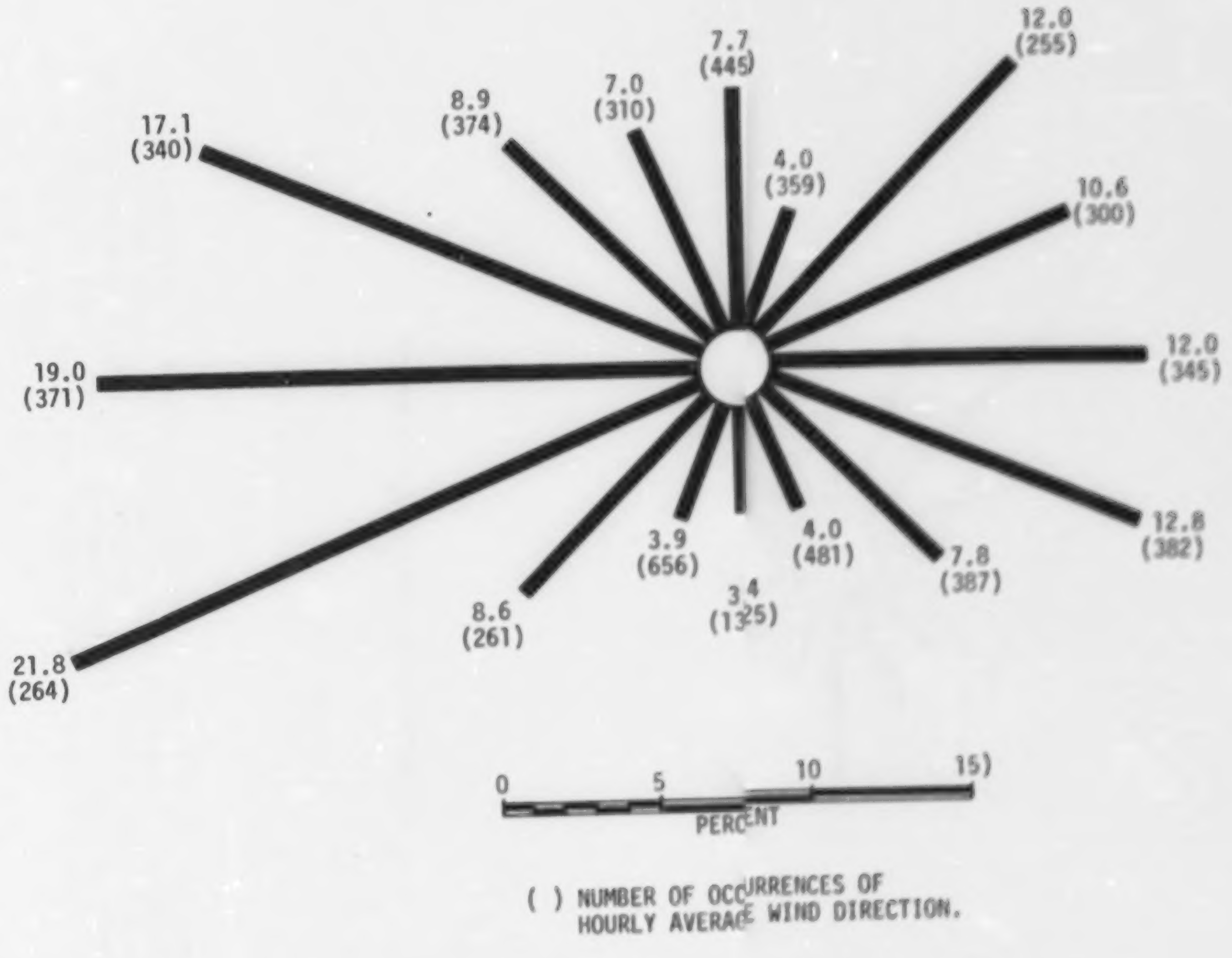


Figure 36. Police Garage soiling index pollution rose. Percentage of occurrences of wind directions accompanied by Coh values > 0.9 during the period November 1966 through October 1967. Meteorological data is from the UMKC site. Number of hours of pollutant sampling is 7968. Hours of pollutant sampling with missing meteorological data is 1113.

The soiling index pollution rose for the UMKC Campus station (Figure 37) includes 3.5 percent of all soiling index data for this station. It shows that northeast through east winds are frequently associated with soiling index values greater than 0.9 Coh; 25 percent of such values are associated with winds from the direction of the Blue River Valley.

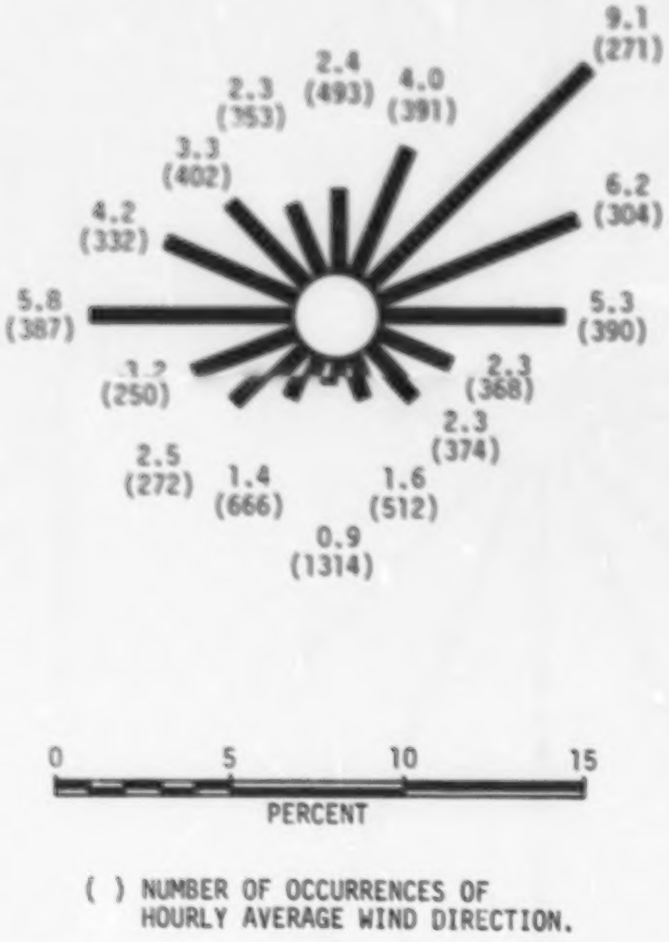


Figure 37. UMKC soiling index pollution rose. Percentage of occurrences of wind directions accompanied by Coh values > 0.9 during the period November 1966 through October 1967. Meteorological data is from the UMKC site. Number of hours of pollutant sampling is 7984. Hours of pollutant sampling with missing meteorological data is 905.

The highest soiling index values recorded during the study were those observed at the Morse School station. The soiling index pollution rose (Figure 38) is for values greater than 1.9 Coh. It includes 4 percent of all soiling index data collected at this station. The rose indicates that there are significant sources of soiling particulates east through southeast and west-southwest through west-northwest from the school. Winds from these directions were associated with 16 percent and 25 percent, respectively, of the values greater than 1.9 Coh. Industrial sources and open-burning dumps in the Kansas River Valley generally lie in these directions from the station.

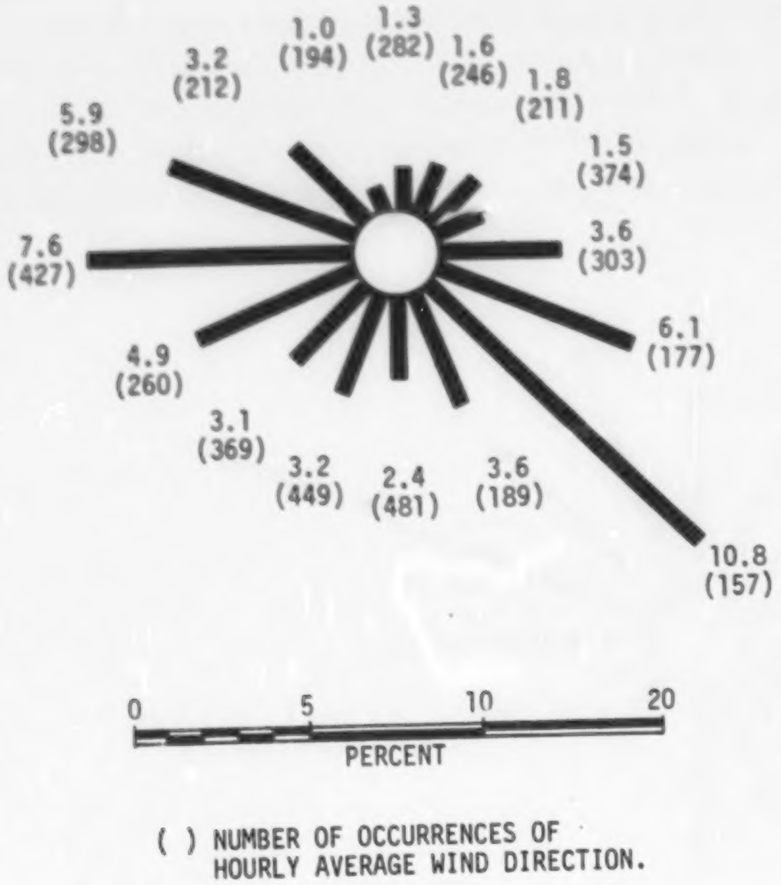


Figure 38. Morse School soiling index pollution rose. Percentage of occurrences of wind directions accompanied by Coh values > 1.9 during the period November 1966 through July 1967. Meteorological data is from the Morse School site. Number of hours of pollutant sampling is 6100. Hours of pollutant sampling with missing meteorological data is 1471.

VISIBILITY REDUCTION

The U.S. Weather Bureau makes hourly observations of visibility at Municipal Airport. These observations indicate the visual range in miles. When less than 7 miles is reported, the cause of visibility reduction is also reported. Among the possible causes of this reduction is smoke, either alone or mixed with haze or fog.

All reported cases of visibility reduction caused by smoke alone, smoke and haze, or smoke and fog during the study period from November 1966 through October 1967 were tabulated. Smoke was reported to reduce visibility a total of 8.4 percent of the time. The wind direction associated with each report of smoke was tabulated. From this, a smoke rose, which indicates the percent of smoke occurrences associated with each wind direction, was constructed. The smoke rose in Figure 39 indicates that northeast through east winds were associated with 29 percent of the occurrences of smoke and south through southwest winds accompanied 20 percent of the occurrences. These directions contributed to visibility reduction 2.7 percent and 1.8 percent of all time, respectively. This smoke rose is almost *identical to one obtained for the first 10 months of 1966*, which was presented in the Phase I report.

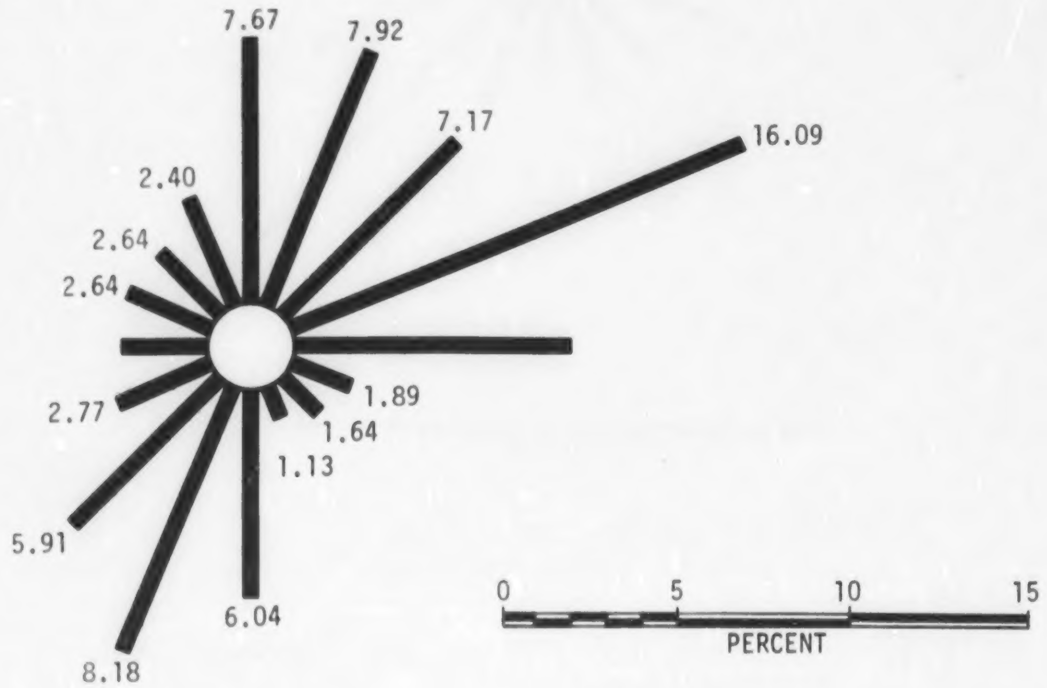


Figure 39. Percentage frequency of occurrence of wind directions when smoke was reported at Municipal Airport. November 1966 through October 1967.

The northeast through east directions indicate that the smoke was from particulate sources in North Kansas City, Missouri, and from sources near the confluence of the Missouri and Blue Rivers. These are the most significant directions, especially in the spring, when they produced 40 percent of the occurrences of visibility reduction by smoke. The south through southwest directions indicate smoke from the numerous sources in the Kansas River Valley. These directions were especially important in the winter months when they accompanied 35 percent of the occurrences of smoke.

## TURBIDITY MEASUREMENTS

Atmospheric turbidity may be considered a measure of the reduction of visible solar radiation intensity in a cloud-free atmosphere. The reduction in intensity is caused by attenuation, especially scattering, due to suspensoids such as smoke, dust, and haze. In general, the smaller the turbidity, the less the attenuation and the fewer particles there are in the atmosphere. Turbidity measurements can be used for a quick appraisal of the air pollution envelope over an area. The measurements may be interpreted as an indication of how "dirty" the air is.

Turbidity measurements were made regularly at Municipal Airport from November 1966 through November 1967. Turbidity was also measured at a number of other locations across the United States. Two locations that can be compared with Kansas City are St. Louis, Missouri, another mid-continent urban location, and Huron, South Dakota, a rural or "clean" site.

In general, emissions, and the resultant atmospheric concentrations of particulate pollutants, increase with population in an urban area. The Kansas City area population is about one-half that of the St. Louis area. The average turbidity values for the two locations generally reflect this size difference, although other factors such as the location of the observing site within the city are important. The 13-month average for St. Louis was 0.153; for Kansas City, it was 0.123, or only 80 percent of the St. Louis value. Kansas City, though, had an average value of twice that obtained at the rural site in Huron, South Dakota.

For the 7 months, May through November 1967, turbidity measurements were also made in downtown Kansas City. Average values were determined from cases when the measurements were made at the same time at both locations. Based on 80 of these observations, the following average turbidity values were found: Municipal Airport, 0.135 and downtown Kansas City, 0.122. The valley location appears to be slightly dirtier than the other site, although the difference is small. The fact that most particulate sources are in the river valleys contributes to the higher values observed at the airport.

## GEOGRAPHIC DISTRIBUTION OF POLLUTANT CONCENTRATIONS

The geographic distribution of average suspended particulate concentrations is given in Figure 40. This distribution is for the averages of all data collected at all sites for the period October 1966 through October 1967. The highest average concentrations ($\geq$125 $\mu g/m^3$) occurred over the Fairfax and Kansas River Valley industrial districts. Average concentrations greater than or equal to 100 $\mu g/m^3$ were generally confined to areas in or along the river valleys. Areas adjacent to these valleys experienced average concentrations of less than 100 $\mu g/m^3$. There was no notable variation in this geographic distribution with seasons. As an example, the distribution during the spring months (Figure 41) is almost identical.

The geographic distribution of average settleable particulate loading collected from January through October 1967 is given in Figure 42. The areas in which the greatest amounts of settleable particulates were measured are along the Blue River and north across the Missouri River through North Kansas City. This same general pattern was seen for the spring months as evidenced by Figure 43; however, during spring the values were generally higher because of the windy, rainy conditions during these months. Rain causes washout of particles from the air, and strong winds tend to re-entrain surface layers of dust.

The geographic distribution of sulfation levels in the Kansas City area is shown in Figure 44. This distribution was obtained from the average of all sulfation data collected at all sampling sites during the period January through October, 1967. It can be seen that average sulfation values equal to or greater than 0.5 mg $SO_3$/100 $cm^2$-day, equivalent to an average monthly $SO_2$ level of approximately 0.02 ppm, occurred mainly near the confluences of the Kansas and Blue Rivers with the Missouri River. Both of these locations are near several large combustion and process sources of sulfur dioxide. The high sulfation values extend northward from the source areas due to the prevailing southerly winds.

A geographic distribution for just the summer months (June - August, 1967) of the sampling period (Figure 45) indicates a similar pattern with the maxima in the same areas. Since power plant $SO_2$ emissions are relatively small at this time of year, the highest values are believed to result mainly from process emissions from the refinery just to the south.

As shown in Figure 46, the winter months (January-February, 1967) have a distribution that reflects the greater $SO_2$ emissions at this time of year. Average sulfation values of at least 0.5 mg $SO_3$/100 $cm^2$-day cover a large part of the study area and are not confined to the river valleys. Further, an area of maximum sulfation values, 0.75 mg/100 $cm^2$-day, which is equivalent to an average monthly $SO_2$ concentration of approximately 0.03 ppm, existed at the confluence of the Kansas and Missouri Rivers.

The generally southerly shift of the area of maximum sulfation levels is due to the winter increase in northwesterly winds and to the large seasonally oriented $SO_2$ emissions from the power plants that surround the area. Examination of a considerable amount of sulfur dioxide monitoring data, obtained in approximately ten large urban areas over the past 5 years, reveals that when a seasonal or yearly average of 0.03 ppm is encountered, frequency distributions of the daily averages invariably exceed 0.10 ppm 1 to 3 percent of the time. It therefore seems reasonable to expect that at a site in the Kansas City area where the seasonal average approximated 0.03 ppm, at least on one occasion the daily average reached 0.10 ppm sulfur dioxide.

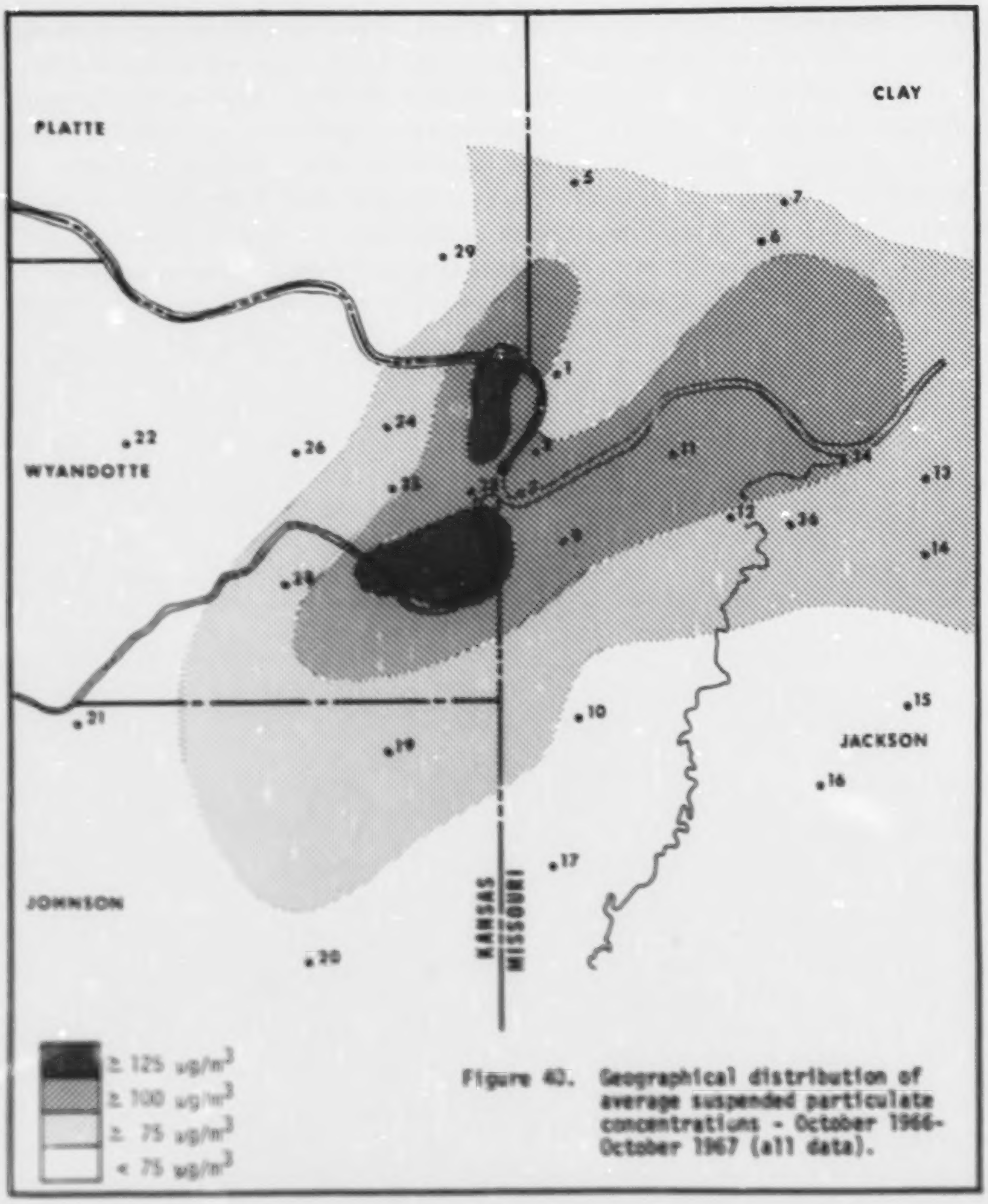

CLAY
PLATTE
WYANDOTTE
JACKSON
JOHNSON
KANSAS
MISSOURI
5
7
6
29
1
24
22
26
3
11
34
13
25
12
36
9
14
28
21
10
15
19
16
17
20
≥ 125 µg/m$^3$
≥ 100 µg/m$^3$
≥ 75 µg/m$^3$
< 75 µg/m$^3$

Figure 40. Geographical distribution of average suspended particulate concentrations - October 1966-October 1967 (all data).

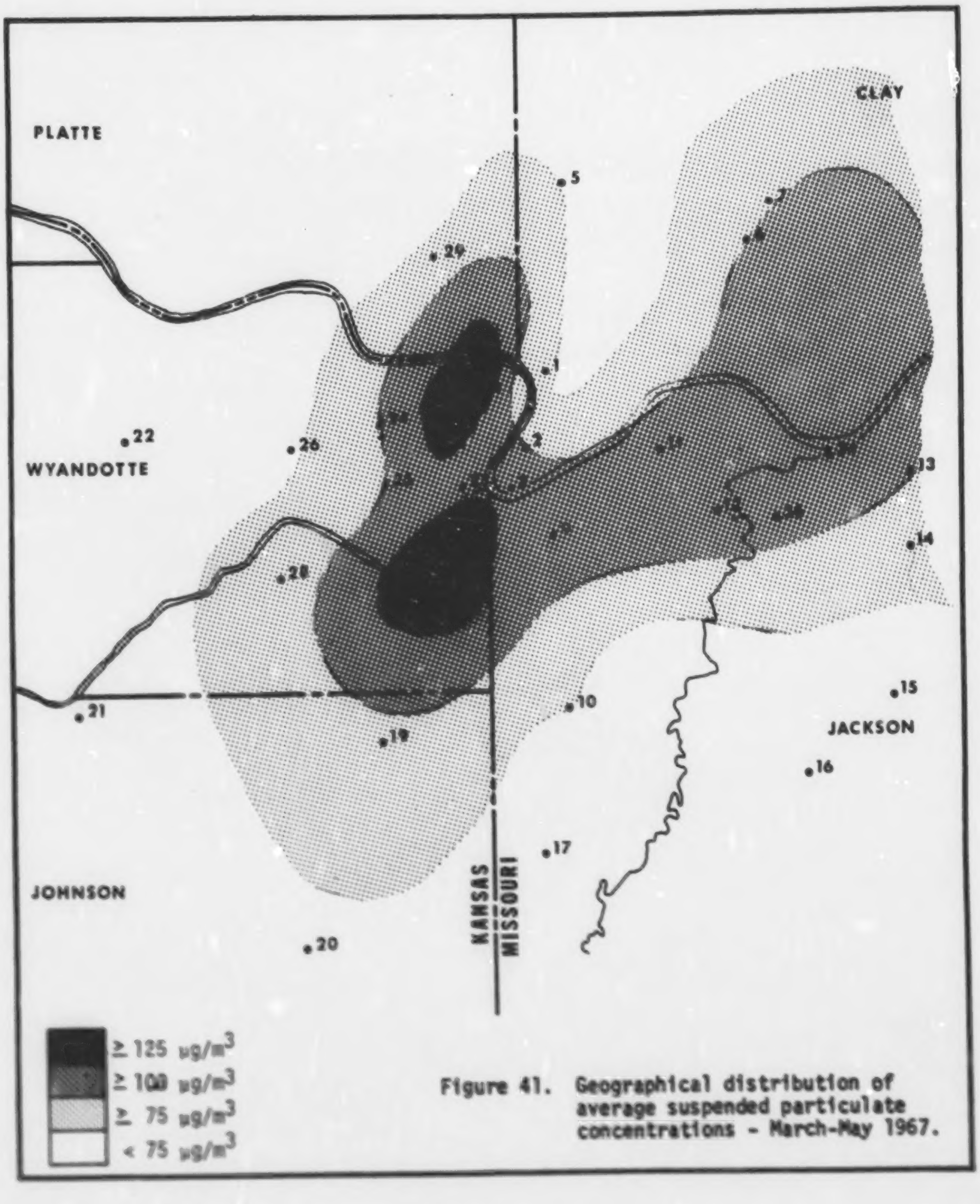

PLATTE
CLAY
WYANDOTTE
JOHNSON
JACKSON
KANSAS
MISSOURI
5
7
6
29
1
22
26
2
13
14
28
10
15
21
19
16
17
20
≥ 125 µg/m³
≥ 100 µg/m³
≥ 75 µg/m³
< 75 µg/m³

Figure 41. Geographical distribution of average suspended particulate concentrations - March-May 1967.

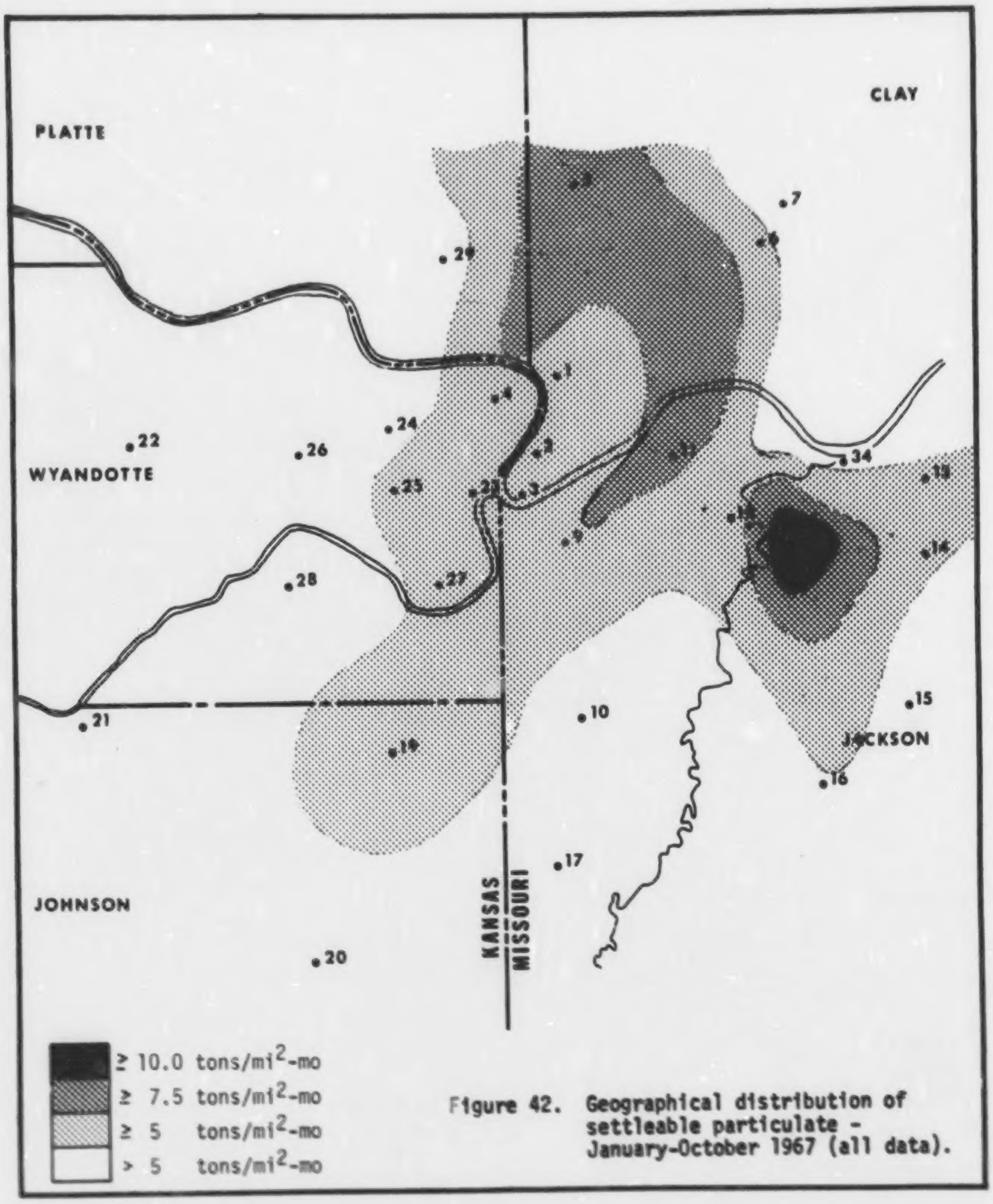

PLATTE
CLAY
WYANDOTTE
JOHNSON
JACKSON
KANSAS
MISSOURI
29
7
6
1
4
24
22
26
2
11
34
13
25
23
3
12
9
14
28
27
21
19
10
15
16
17
20
≥ 10.0 tons/mi$^2$-mo
≥ 7.5 tons/mi$^2$-mo
≥ 5 tons/mi$^2$-mo
> 5 tons/mi$^2$-mo

Figure 42. Geographical distribution of settleable particulate - January-October 1967 (all data).

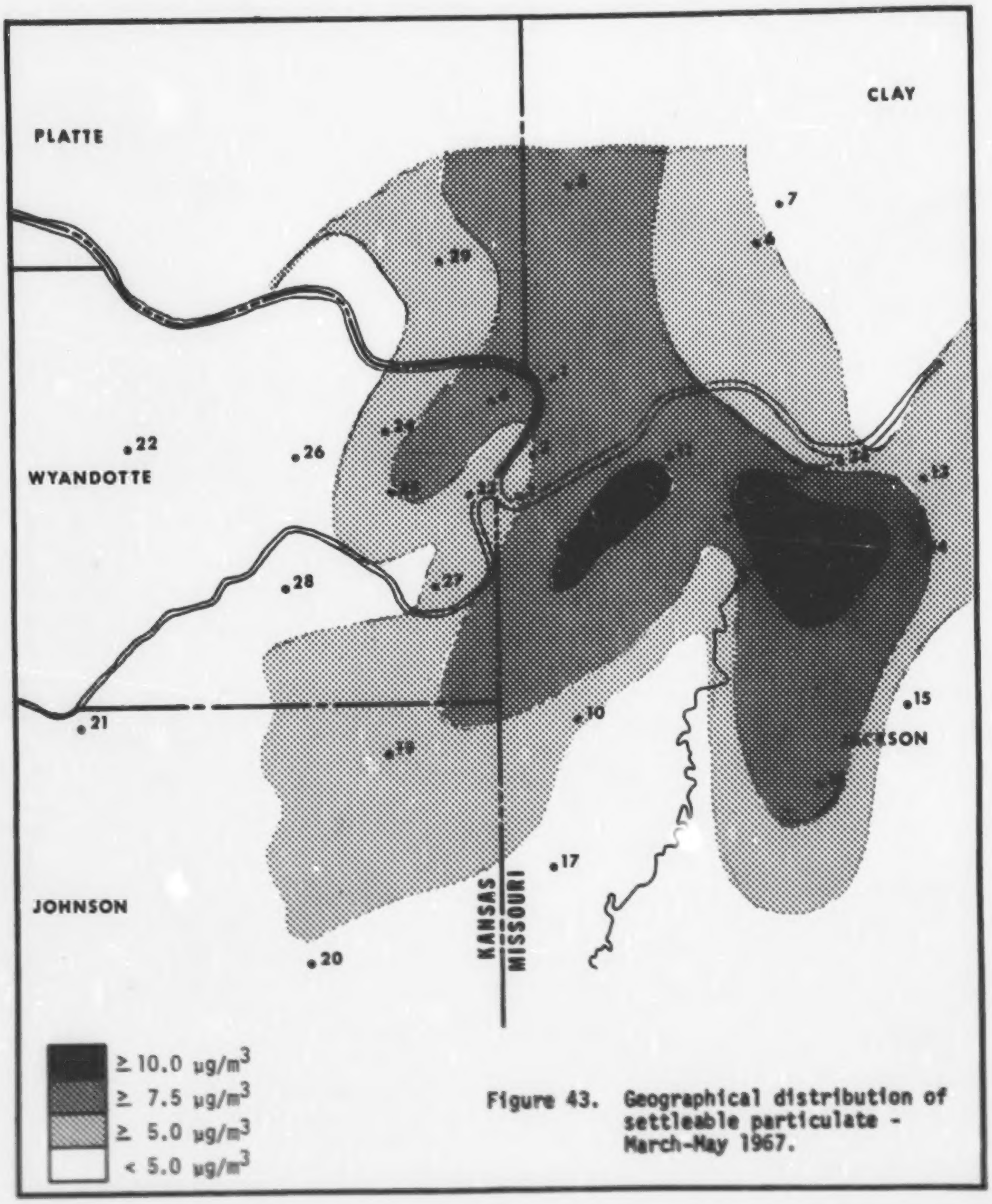

CLAY
PLATTE
7
6
29
22
WYANDOTTE
26
24
27
28
21
19
10
15
13
JACKSON
17
JOHNSON
KANSAS
MISSOURI
20
≥ 10.0 μg/m3
≥ 7.5 μg/m3
≥ 5.0 μg/m3
< 5.0 μg/m3

Figure 43. Geographical distribution of settleable particulate - March-May 1967.

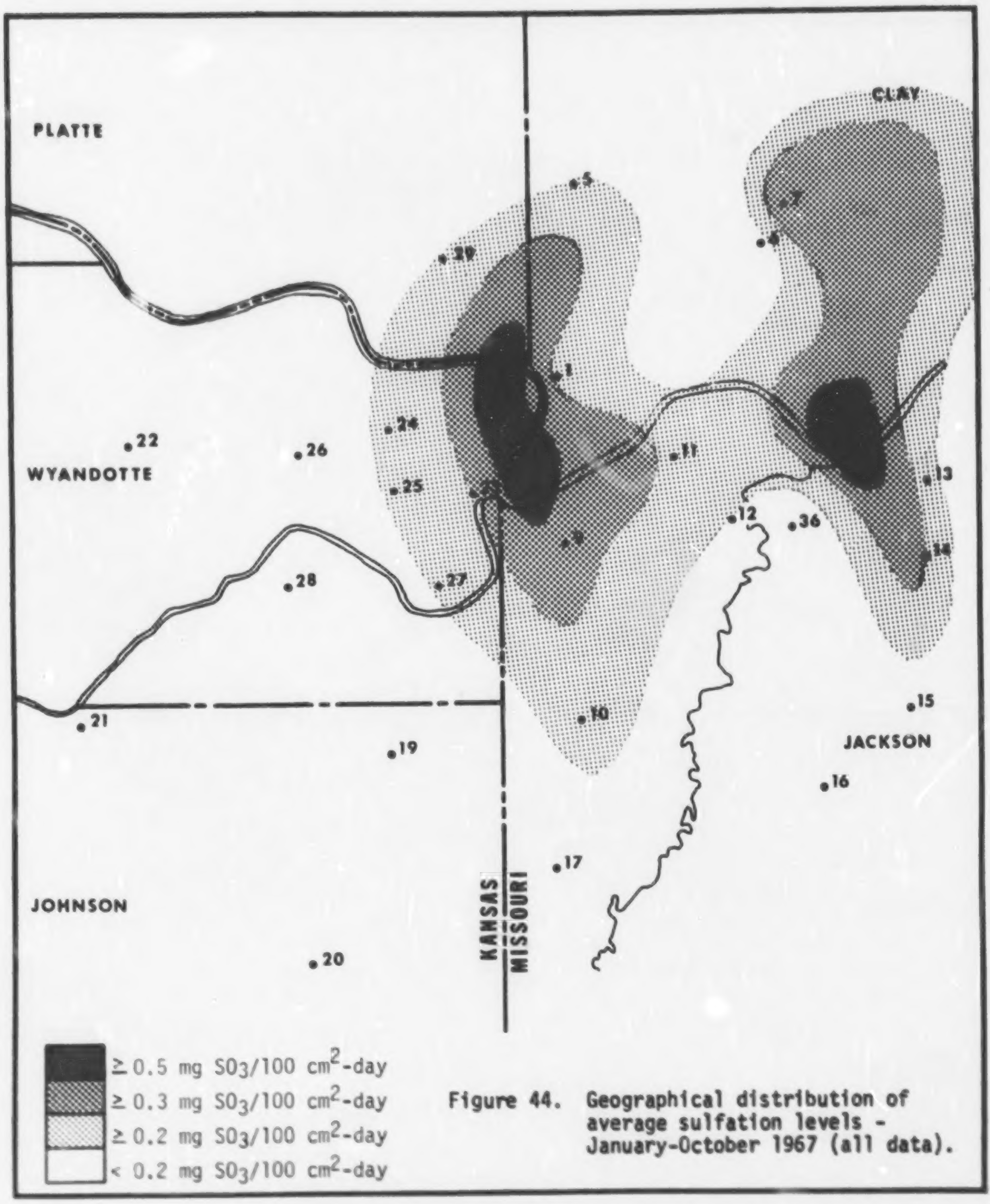

PLATTE
CLAY
WYANDOTTE
JACKSON
JOHNSON
KANSAS
MISSOURI
5
29
7
8
1
22
26
24
11
25
13
12
36
9
14
28
27
15
10
21
19
16
17
20
■ ≥ 0.5 mg SO3/100 cm2-day
▩ ≥ 0.3 mg SO3/100 cm2-day
▨ ≥ 0.2 mg SO3/100 cm2-day
□ < 0.2 mg SO3/100 cm2-day

Figure 44. Geographical distribution of average sulfation levels - January-October 1967 (all data).

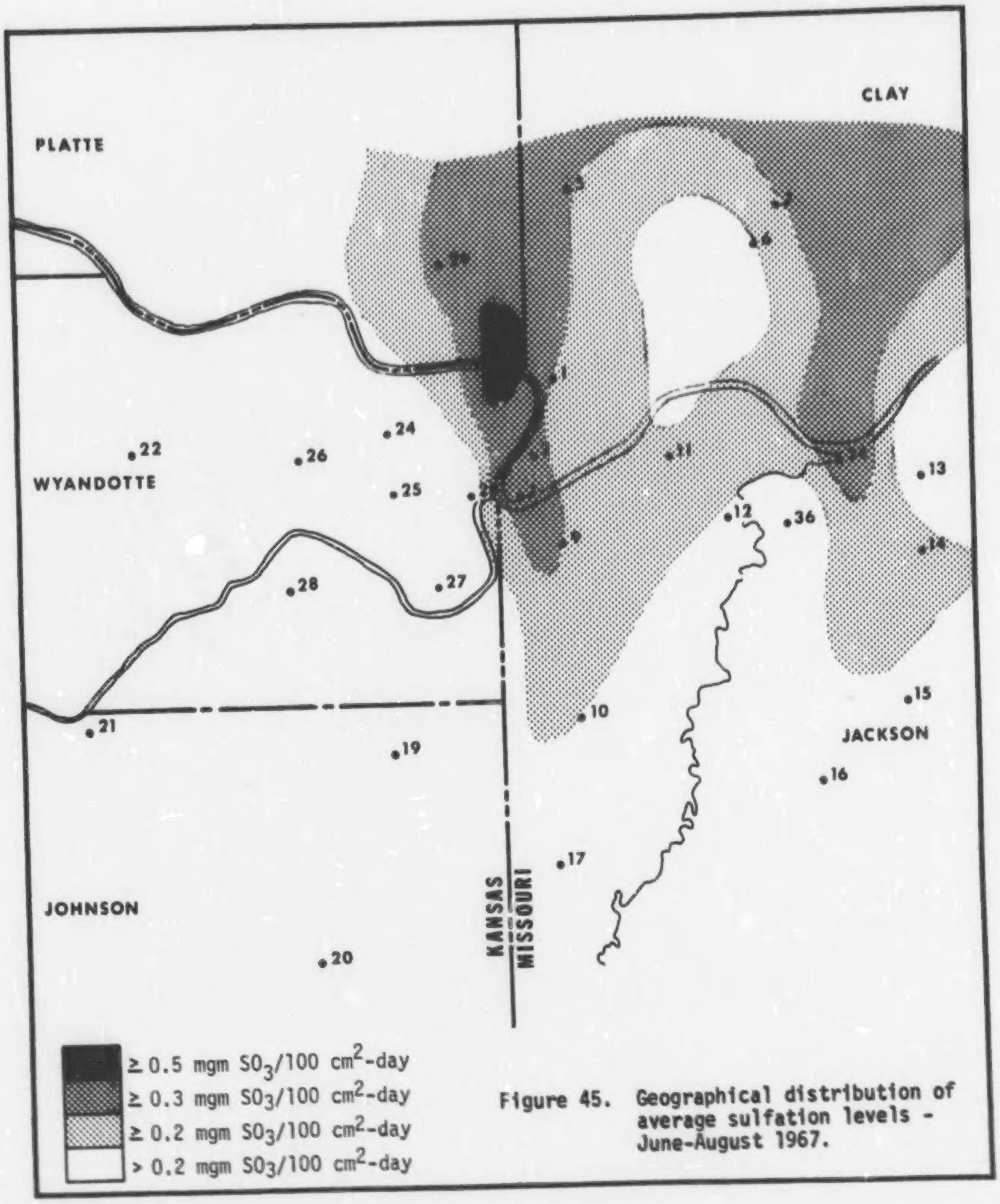

CLAY
PLATTE
WYANDOTTE
JOHNSON
JACKSON
KANSAS
MISSOURI
22
26
24
25
28
27
21
19
20
17
10
11
12
36
13
14
15
16
≥ 0.5 mgm $SO_3$/100 $cm^2$-day
≥ 0.3 mgm $SO_3$/100 $cm^2$-day
≥ 0.2 mgm $SO_3$/100 $cm^2$-day
> 0.2 mgm $SO_3$/100 $cm^2$-day

Figure 45. Geographical distribution of average sulfation levels - June-August 1967.

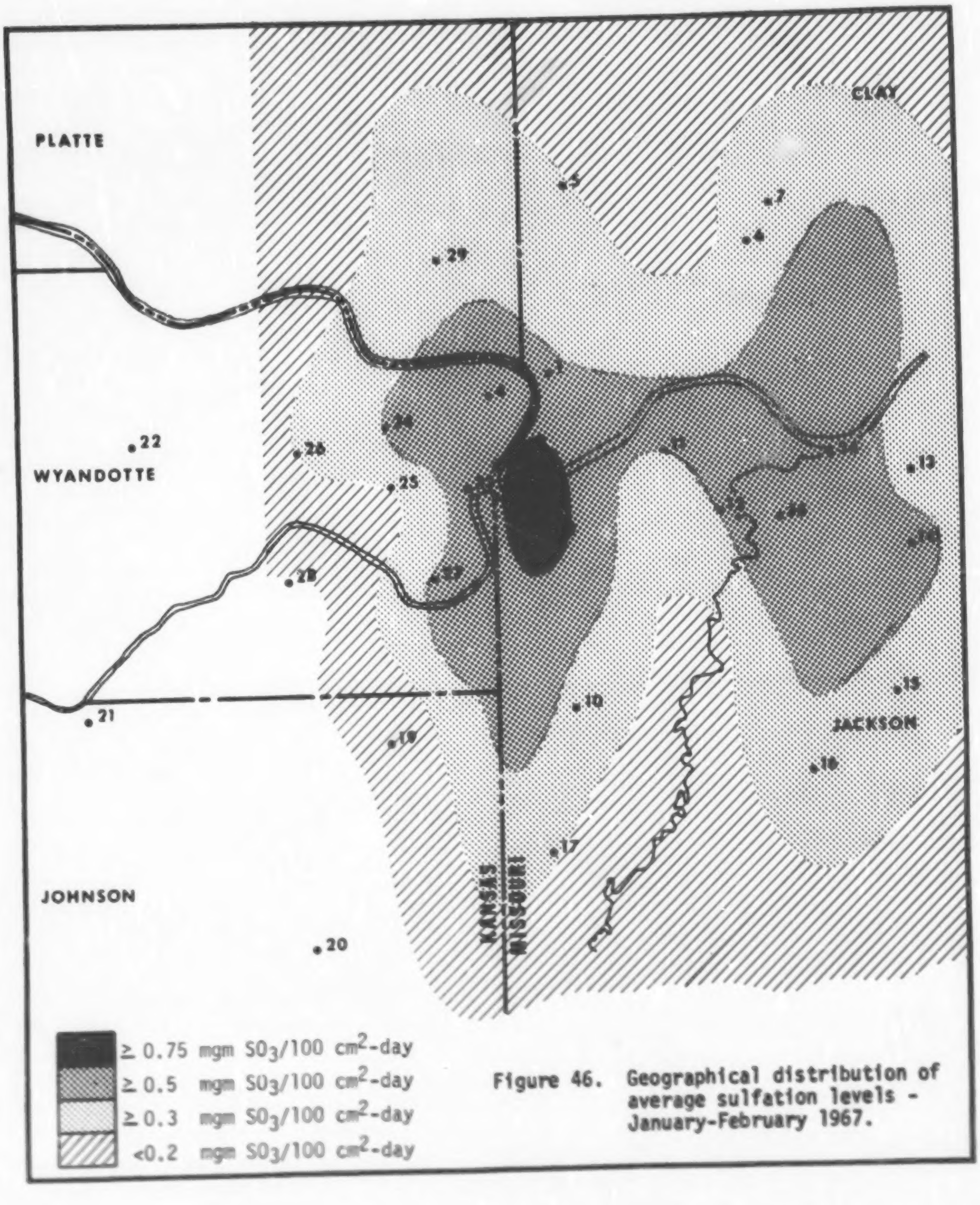

PLATTE
CLAY
.5
.7
.6
.29
.22
WYANDOTTE
.26
.25
.28
.21
.19
.10
.17
.13
.15
.16
JACKSON
JOHNSON
.20
KANSAS
MISSOURI
≥ 0.75 mgm $SO_3$/100 $cm^2$-day
≥ 0.5 mgm $SO_3$/100 $cm^2$-day
≥ 0.3 mgm $SO_3$/100 $cm^2$-day
<0.2 mgm $SO_3$/100 $cm^2$-day

Figure 46. Geographical distribution of average sulfation levels - January-February 1967.

# IV. PARTICULATES AND SULFUR OXIDES EFFECTS AND STANDARDS

## PARTICULATE POLLUTION

### Effects

The principal effects attributed to particulate air pollution are soiling of property and goods, deterioration of materials, restriction of visibility, and creation of a significant psychological nuisance factor. Its adverse effects on community health, although somewhat more subtle, are nevertheless just as significant.

There are four areas of concern relative to the health effects of particulate matter pollution on humans:

1. The ability of the respiratory tract to separate particulates from inhaled air and retain them in the lungs.

2. The presence in some particulate material of metallic or mineral substances having toxic or other physiological effects.

3. The presence in some particulate material of polycyclic hydrocarbons having demonstrated carcinogenic properties.

4. The demonstrated ability of fine particles to enhance the harmful physiological activity of gaseous pollutants or to convert these to other more harmful materials when both are simultaneously present in inhaled air. Of particular concern in this area is the ability of certain airborne mineral substances to increase the rate at which atmospheric sulfur dioxide is oxidized to the much more physiologically active sulfur trioxide. Also, while sulfur dioxide gas appears to be relatively harmless in the upper respiratory tract, it is seldom inhaled alone. It is adsorbed on particulate matter and transported into the sensitive portions of the lungs.

The size of airborne particles has an important bearing on whether, and to what extent, they reach the lungs. Most coarse material, particles about 5 microns or more in diameter, lodges in the upper respiratory passages. Smaller particles are more likely to penetrate into the lungs; in the range of about 1 to 5 microns the rate of lung deposition increases with decreasing particle size. Particles smaller than 2 to 3 microns usually reach the deeper structures of the lungs, where there is no protective mucous blanket. A major portion of the suspended particulate matter in urban air falls into this latter category.

The primary effect of inert airborne solids on community welfare is soiling. Although these particles may directly cause only minimal deterioration, the cleaning of soiled objects is costly and the cleaning process shortens the useful life of many items upon which grime is deposited. A current survey of approximately 6500 families in metropolitan Washington, D. C., an area with annual suspended particulate levels generally 10 to 20 percent lower than those in the Kansas City area, revealed that the average per capita cost for household maintenance and cleaning due to polluted air is approximately $100 annually. Impressive as this figure is, it represents only a relatively minor portion of the economic impact of polluted air on the population. Items such as the cost of health effects in terms of medical care and drugs, lost time at work, lowered property values, agricultural damage, and accelerated corrosion were not included.

### Criteria

Table 41 presents a summary of the current air quality standards for particulates adopted for the St. Louis, Missouri, Metropolitan area.

Table 41. AIR QUALITY STANDARDS FOR PARTICULATES FOR ST. LOUIS, MISSOURI (Standard not to exceed stated concentrations.)

| | |
|---|---|
| Suspended particulate - high-volume sampler | |
| 75 $\mu g/m^3$ | Annual geometric mean |
| 200 $\mu g/m^3$ | 1 percent of days per year |
| Suspended particulate - soiling, AISI sampler | |
| 0.4 Coh/1000 lineal feet | Annual geometric mean |
| Settleable particulate - dustfall | |
| 10 tons/mi$^2$-mo | 3-month average above background (5 tons/mi$^2$-mo) all areas except zoned heavy industrial |
| 25 tons/mi$^2$-mo | 3-month average above background (5 tons/mi$^2$-mo) heavy industrial areas |

## SULFUR OXIDES POLLUTION

### Effects

There is evidence that the sulfur oxides family of pollutants, specifically, sulfur dioxide, sulfur trioxide, their acids, and their acid salts, aggravate existing human respiratory disease as well as contribute to the development of some of them. As previously indicated, the effects on human health become considerably more pronounced when these contaminants are found in combination with suspended particulate matter.

The contribution of sulfur oxides pollution during disaster episodes, i.e., when levels of these contaminants (and others) are excessively high, has been documented. Low-level, long-term exposure, as well as short-term fumigations affect not only the health, but the social and economic welfare of the urban community. The tabulation in Table 42 summarizes some of these multiple effects, which have been determined from a significant body of scientific evidence.

Table 42. SUMMARY OF MULTIPLE EFFECTS FROM EXPOSURE TO SULFUR DIOXIDE

| Concentration and time | |
|---|---|
| 0.02 to 0.03 ppm for 1 year | Increased respiratory disease death rates in humans<br>Corrosion of metals becomes significant<br>Injury to perennial vegetation |
| 0.1 to 0.3 ppm for 2 to 4 days | Increases to hospital admissions and mortality due to cardiorespiratory disease<br>Increase in prevalence of rhinitis, sore throat, cough, and eye irritation<br>Mild acute injury to sensitive vegetation |
| 0.3 to 1.0 ppm for 1 hour or less | Threshold for increased respiration and and pulse rates of humans<br>Taste and odor threshold for humans |

### Criteria

Table 43 presents a summary of current air quality standards for sulfur pollutants adopted for the St. Louis, Missouri, Metropolitan area.

Table 43. AIR QUALITY STANDARDS FOR SULFUR OXIDES FOR ST. LOUIS, MISSOURI
(Standard not to exceed stated concentration)

| | |
|---|---|
| Sulfur dioxide | |
| 0.02 ppm | Annual average |
| 0.10 ppm | 24-hour average, 1% of days in any 3 consecutive months |
| 0.20 ppm | 1-hour average, once in any 4 consecutive days |
| Sulfuric acid mist | |
| 4 $\mu g/m^3$ | Annual average |
| 12 $\mu g/m^3$ | 1% of time |
| 30 $\mu g/m^3$ | 1-hour average, 1% of time |

# REFERENCES

1. Kansas City, Kansas - Kansas City, Missouri Air Pollution Abatement Activity. Visibility at Municipal and Fairfax Airports. National Center for Air Pollution Control. Cincinnati, Ohio. January 1967.

2. United States Weather Bureau, 1955, Meteorology and Atomic Energy, U. S. Government Printing Office. 1955.

3. Korshover, J. Climatology of stagnating anticyclones east of the Rocky Mountains, 1936 - 1965. Public Health Service Publication No. 999-AP-34. U. S. Department of Health, Education, and Welfare. Public Health Service. National Center for Air Pollution Control. Cincinnati, Ohio. 1967.

4. Turner, D. B. Relationships between 24-hour mean air quality measurements and meteorological factors in Nashville, Tennessee. Journal of Air Pollution Control Association. 11:483-488. October 1961.

5. Hosler, C. R. Low level inversion frequency in the contiguous United States. Monthly Weather Review. 89:319-39. September 1961.

6. Climatography of United States. No. 82-23. Summary of hourly observations, Kansas City, Missouri Municipal Airport 1951 - 60. U. S. Government Printing Office. Washington, D. C. 1963.

7. Uniform summary of surface weather observations. Grandview, Missouri. Richards-Gebaur Air Force Base. April 1954 - December 1962. Climatic Center, USAF. Asheville, North Carolina. 1963.

8. Surface Weather Observations. WBAN Form 10A. U. S. Weather Bureau, Municipal Airport, Kansas City, Missouri. 1961 - 1963.

9. Holzworth, G. C. Mixing depths, wind speeds and air pollution potential for selected locations in the United States. Journal of Applied Meteorology. 6(6):1037-44. December 1967.

10. Gifford, F. A. Use of routine meteorological observations for estimating atmospheric dispersion. Nuclear Safety, 2(4), June 1961.

# APPENDICES

Appendix A. Phase I Conclusions and Recommendations
Appendix B. Description of Project Design
Appendix C. Aerometry Operation and Techniques
Appendix D. Emissions Inventory Procedure
Appendix E. Pollutant Measurement Data

**Preceding page blank**

## APPENDIX A. CONCLUSIONS AND RECOMMENDATIONS ON INTERSTATE AIR POLLUTION - KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, METROPOLITAN AREA, JANUARY 1967

### General Conclusions Reached by Official Participants of Kansas City, Kansas - Kansas City, Missouri, Interstate Air Pollution Abatement Conference

A. Occurrence of Air Pollution Subject to Abatement Under the Clean Air Act

Air pollutants discharged from large industrial and refuse disposal operations in the State of Kansas and in the State of Missouri cause or contribute to reduced visibility, which creates hazards to air transportation at Fairfax Airport, Kansas City, Kansas, and at Municipal Airport, Kansas City, Missouri. The Kansas City metropolitan area, in fact, has a common air mass, and any pollutants discharged into that air mass from whatever sources, cause or contribute to air pollution that may be carried indiscriminately throughout the interstate area, subject only to the vagaries of wind and weather.

Such interstate air pollution endangers the welfare and safety of persons in interstate travel and, therefore, is subject to abatement under Section 105, Title I of the Clean Air Act (42 U.S.C. 1857, et seq.).

B. Adequacy of Measures Taken Toward Abatement of Air Pollution

It must be concluded that totally insufficient and inadequate action has been taken toward abating air pollution in the interstate area encompassing the Fairfax and Municipal airports in Kansas and Missouri, respectively. In fact, it would be difficult to demonstrate that any effective action has been taken - except in the very recent past, and largely since announcement of this abatement action - by either the polluters or the responsible governments to cope with the obvious air pollution problem.

C. Nature of Delays in Abating Pollution

The most comprehensive activity in this area has been that undertaken by the Wyandotte County - Kansas City, Kansas, Health Department, aided by a program grant under the Clean Air Act. Largely through the efforts of the Director of Environmental Health, the air pollution problem has been defined in the Kansas portion of this interstate area, and emission standards were enacted just last week. Their effectiveness and the vigorousness of enforcement remain to be seen.

Proceding page blank

The State of Kansas has no air pollution control law and minimal attention is devoted to the problem.

The State of Missouri passed a comprehensive air pollution control law, which became effective October 13, 1965. To date, however, the full-time professional staff of the Air Conservation Commission consists of one person--a devoted, hard-working, dedicated individual, to be sure, but nevertheless only one person. The Commission, therefore, has been unable to provide technical assistance, comprehensive services and routine guidance to local agencies throughout the state. It has not yet adopted standards or regulations which are applicable in the Kansas City area.

The Kansas City, Missouri, Health Department has received a grant under the Clean Air Act and has an embryonic program underway. Also, the Department has attempted--unsuccessfully, so far--to interest adjoining and surrounding communities to join in areawide assessment of air pollution in the Missouri portion of the interstate area.

In short, there are no effective local ordinances, regulations, or control programs; there are, as yet, no applicable state standards, regulations or comprehensive programs; and there is no legally constituted interstate agency with rule-making and enforcement authority.

It must be concluded that the air pollution problem in the Kansas City, Kansas-Kansas City, Missouri, interstate area developed and grew because of almost total inaction. Under existing legal authority, neither state can prevent or abate air pollution which comes from sources located in the other state. Accordingly, the air pollution problem will persist and probably grow worse until a program with adequate regulatory and enforcement authority to deal with the problem in both states, on a coordinated and uniform basis, is established and becomes operational.

## RECOMMENDATIONS BY THE SECRETARY
## U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

It is found that effective progress toward abatement of the air pollution discussed at this conference is not being made, and that the welfare and safety of persons in interstate travel is endangered. Therefore, requisite remedial action is recommended. It may be noted that there was unanimous concurrence in these recommendations by all official conference participants.

## RECOMMENDATION I

## INTERSTATE AIR POLLUTION CONTROL AGENCY

It is found that:

1. Uniform enforcement of control measures is required to obtain a uniform quality of air throughout the Kansas City metropolitan area, and to ensure that no portion of the area provides a haven for sources of pollution.
2. To accomplish this result, an agency must be established and vested with adequate legal authority.
3. Legislation by the States of Kansas and Missouri is needed to create such an agency.

Therefore, it is recommended that:

1. Legislation be enacted immediately that will establish such an agency.
2. Such legislation, in addition to other appropriate authority, should provide:
    a. Authority to establish uniform ambient air quality standards for at least the six-county area involved in this abatement conference; i.e., Wyandotte and Johnson Counties in the State of Kansas, and Platte, Clay, Jackson, and Cass Counties in the State of Missouri. Additional authority reasonably might be provided to authorize the interstate agency to include additional counties or to delimit as air pollution control regions other border areas in both states that share an air pollution problem, and to establish uniform air quality standards for such other regions.

    b. Adequate rule-making and enforcement authority to abate, control, and prevent air pollution originating in the six-county Kansas City metropolitan region (and in such other regions as the interstate air pollution control agency may establish) to ensure the achievement of such air quality standards.

    c. Authority to establish a regional enforcement agency in the Kansas City metropolitan region (and in any other region established by the interstate agency), with appropriate representation of local governments, that will meet the enforcement standards of the interstate agency and will be supported by local financial resources.

    d. Assurance of adequate budgetary support by the states.

e. Federal representation on the interstate agency, with the same vote as any state, in recognition of the ultimate Federal interest in, and responsibility for, the quality of the air as it affects the health or welfare of any persons.

The Kansas City, Kansas-Kansas City, Missouri, Interstate Air Pollution Abatement Conference shall remain in continuing session, subject to the call of the Presiding Officer or his designated representative, until an interstate air pollution control agency with adequate legal authority, as outlined above, is established, staffed, and effectively operational.

## RECOMMENDATION II

## REFUSE DISPOSAL AND SALVAGE OPERATIONS

It is found that:

1. Refuse disposal by open burning accounts for approximately 20 percent of the total particulate emissions in the survey area (the area within a four-mile radius of the confluence of the Missouri and Kansas Rivers), and that observations made throughout the entire metropolitan area indicate this practice constitutes the largest single area-wide source of air contamination which obstructs visibility.
2. These emissions substantially add to the background of particulate pollution which, when combined with nearby point source emissions, substantially curtails visibility and results in hazardous flight and traffic control conditions at Municipal and Fairfax Airports.
3. The burning of refuse and other wastes at the site of the Doepke Disposal Service in Kansas City, Kansas, results in the frequent emission of clouds of dense smoke which obstruct and curtail visibility for aircraft operations at the Fairfax Airport to such a degree that it constitutes an imminent danger to such operations.

Therefore, it is recommended that:

The disposal of refuse, or the conduct of a salvage operation, by burning other than in a multiple-chamber incinerator whose emissions may not exceed 0.2 grains of particulate matter per standard dry cubic foot of exhaust gas corrected to 12 percent carbon dioxide, shall be prohibited:

a. In the survey area, no later than August 1, 1967, except that disposal of refuse and other wastes by burning at the site of Doepke Disposal Service in Kansas City, Kansas, shall be prohibited immediately upon the issuance of these recommendations.

b. In all other portions of the Kansas City Standard Metropolitan Statistical Area, no later than July 1, 1968, except that such prohibition shall not apply to individual household refuse disposal in sparsely populated areas.

## RECOMMENDATION III

## CONTROL OF PROCESS EMISSIONS

It is found that:

1. Particulate emissions from industrial sources curtail visibility so as to cause a substantial hazard to air traffic operations at Municipal Airport, Kansas City, Missouri, and Fairfax Airport, Kansas City, Kansas, and that they contribute to the accumulation of atmospheric pollutants causing a reduction of visibility in considerable portions of the bi-state metropolitan area.
2. Technological means for eliminating or reducing these emissions generally are available. In developing abatement schedules, it must be recognized that techniques for control of individual emissions are at different stages of development, the time required for application or installation of control measures may vary widely, and the impacts upon airport operations of emissions from different sources vary in severity.

Therefore, it is recommended that:

1. Discharges into the atmosphere from any source in the survey area shall not exceed a density of 20 percent opacity, such opacity being that which obscures an observer's view to a degree equal an emission designated as No. 1 on the Ringelmann Smoke Chart or on the Public Health Service Smoke Inspection Guide.
2. Upon the issuance of this recommendation, this limitation shall apply to the following sources in the survey area in accordance with the following schedule:

a. Owens-Corning Fiberglas Corp.

| | |
|---|---|
| Glass furnaces emissions | 6 months |
| Forming lines emissions | 12 months |
| Curing ovens emissions | 6 months |
| All other emissions | 12 months |

b. Gustin-Bacon Mfg. Co.

| | |
|---|---|
| Glass furnace emissions | 6 months |
| Forming lines emissions | 12 months |
| Curing ovens emissions | 6 months |
| All other emissions | 12 months |

| | |
|---|---|
| c. U. S. By-Products Corp. | |
| All process combustion emissions | 6 months |
| All air classification emissions | 6 months |
| All fired kiln emissions | 6 months |
| All other emissions | 12 months |
| d. Sonken-Galamba Corp. | |
| All reverberatory and sweat furnaces emissions | 6 months |
| All fired kiln emissions | 6 months |
| All other emissions | 12 months |
| e. Phillips Petroleum Co. | |
| Catalyst regeneration unit emissions | 6 months |
| Complete instrumentation and adjustment of safety flares to prevent operation during malfunction | 6 months |
| All other emissions | 12 months |
| f. Abex Corp. | |
| All emissions | 12 months |
| g. American Alloys | |
| All emissions | 12 months |
| h. Bartlett Grain Co. | |
| All emissions | 12 months |
| i. Bunge Corp. | |
| All emissions | 12 months |
| j. Cook Paint & Varnish Co. | |
| All emissions | 12 months |
| k. Corn Products Co. | |
| All emissions | 12 months |
| l. General Mills | |
| All emissions | 12 months |
| m. Grand Avenue Power Plant | |
| All emissions | 12 months |
| n. International Milling | |
| All emissions | 12 months |
| o. Kaw Power Plant | |
| All emissions | 12 months |

p. Procter & Gamble Co.
    All emissions 12 months

q. Quindaro Power Plant
    All emissions 12 months

r. Rodney Milling
    All emissions 12 months

s. Standard Milling
    All emissions 12 months

t. Wabash, Div. of Ralston Purina
    All emissions 12 months

3. Companies listed in Paragraph 2 of this recommendation shall submit written reports of progress toward accomplishment of this recommendation to their respective state air pollution control agencies 30 days, 90 days, and subsequently at 90-day intervals following issuance of these recommendations, until compliance is reported, and shall forward a copy of each report to the Presiding Officer of the Conference, Abatement Program, National Center for Air Pollution Control, Department of Health, Education, and Welfare, Washington, D. C., 20201.

## RECOMMENDATION IV

## PREVENTION OF AIR POLLUTION AT MID CONTINENT INTERNATIONAL AIRPORT

It is found that:

1. The emission of atmospheric pollutants which cause reduction of visibility in the vicinity of existing airports creates hazards to air traffic using the airports.
2. The prevention of such reduction of visibility in the vicinity of the Mid Continent International Airport, Platte County, Missouri, is of concern to the Manager, Kansas City Area Office, Federal Aviation Agency.

Therefore, it is recommended that:

No new source of particulate emissions be placed in operation in the metropolitan area after issuance of this recommendation, unless there is adequate assurance that such source will meet the requirement of Section I of Recommendation III.

# APPENDIX B. DESCRIPTION OF PROJECT DESIGN

## AIR QUALITY NETWORK

### Scope

The objectives of the air quality investigation were:

1. To assess the sources, characteristics, concentrations, and interstate movement of air pollution that may affect the health and welfare in the Kansas City area.

2. To promote the development of an effective program for abatement and prevention of air pollution in the Kansas City area.

### Criteria for Network Design

Three factors were basic in determining the criteria for network design:

1. Conference date. A general date for reconvening the conference, namely late 1967, permitted the network to be designed for an entire year.

2. Availability of samplers. The first pieces of Public Health Service air quality sampling equipment would remain on line from the Phase I study, and the last of the equipment would be ready in March, 1967.

3. Sampling locations. The network must be designed to acquire data from all seven counties.

From these factors, the following important and controlling considerations for the network evolved:

1. The design should be integrated with the two existing National Air Sampling Network Stations.

2. The design should evolve stations representing areas of habitation or occupation and still others should be placed to note background contamination levels.

3. The design should be oriented to consider the predominant wind directions. Such orientation would increase the efficiency with which the sampling equipment could be used. Not only should the downwind direction be investigated, but the lateral spread of contaminants should also be considered.

Public Health Service Sites

After due consideration, the Field Operations Activity of the Abatement Program selected the major sampling sites. Criteria for selection of the sites were as follows:

1. The site must represent as large an area as possible. It should not be adjacent to a major pollution source, but it should be in a moderately to heavily populated or traveled area, unless the station is used as a background sampling site.

2. The site must be located so that nearly all obstructions are minimal. If obstructions are present, the distance between the site and the obstruction should be at least 2.5 times the difference in height between the sample intake manifold and the height of the nearest obstruction. If obstructions are unavoidable, the nearest obstruction should be to the east of the site.

3. The site should be reasonably convenient to commercial 215- to 230-volt, 100-ampere power.

4. The site should be located so that it is not obviously vulnerable to vandalism or so that precautions against vandalism can be taken.

5. The site should be owned or controlled by persons or agencies sympathetic to the objectives of the project to avoid undue complications in negotiating for access to the site.

A number of potential sites satisfied the criteria. The Waterworks was maintained for reasons of continuity between Phase I and Phase II. The Police Garage was chosen as a site in the commercial area of Kansas City. The UMKC Campus station was selected as representative of a residential area, whereas Morse School is located in an industrial region. All four of these stations were reasonably convenient to the downtown headquarters office.

A description of the characteristics of each major sampling site and meteorological data follows:

Station 1 - Waterworks. This site was located on the northwest corner of the main building at the Kansas City, Missouri Water Treatment Plant. Bluffs enclose the building to the north, but the exposure is excellent from west to south to east.

Station 9 - Police Garage. This site was located on the roof of the Kansas City, Missouri, Police Garage at 13th Terrace and Oak. This building is very low and is enclosed by much higher buildings to the north, west, and south. The exposure to the east was good and the site proved to be an excellent downtown receptor.

Station 10 - UMKC Campus. This site was located on the roof of the maintenance building at the corner of Troost Avenue and 51st on the campus of the University of Missouri at Kansas City. This station provided good exposure in all directions and was reasonably unobstructed.

Station 27 - Morse School. This site was located on the roof of Morse School in the Argentine District of Kansas City, Kansas at the corner of Baltimore and Miami. Although this site was fairly low, the exposure in all directions was excellent.

A listing of all stations and their sampling equipment appears in Appendix C.

## EMISSIONS INVENTORY

### Applications

The objective of this inventory was to locate and quantify emissions from industrial, governmental, commercial, and residential sources for the following applications:

1. To provide evidence of the existence of source emissions within the study area and to define the location, magnitude, frequency, duration, and relative contribution of these emissions.

2. To demonstrate by use of mathematical diffusion models the impact of air pollutants on receptor areas under the variety of meteorological conditions prevalent during the changing climatic conditions of the year.

3. To provide, by correlating the diffusion estimates with actual data from the air quality monitoring network, evidence whether interstate transport of air pollutants can and does occur, and whether it is of sufficient intensity and duration to endanger the health and welfare of the population.

4. To provide background data needed to evaluate the effectiveness of future control programs.

Technique

The technique utilized for this emissions inventory consisted of the following general steps.

1. Division of the survey area into emission zones, based on similarities in land use, population density, fuel-use patterns, vehicular traffic patterns, or other definable homogeneities.

2. Accumulation of data on emission sources that are generally found to be broadly distributed within each zone. Included here are data for residential, institutional, commercial, and industrial space and water heating; on-site refuse incineration; and mobile sources.

3. Accumulation of data on major point sources located at specific sites within each emission zone. Included here are data for major fuel users, large refuse disposal, and industrial pollution sources.

4. Estimation of emissions of sulfur oxides, carbon monoxide, particulates, and hydrocarbons based on fuel composition and quantities, types of processes and equipment, and appropriate emission factors. Where control equipment is utilized, actual or average collection efficiencies corresponding to the type of equipment are employed.

5. Calculation of the zone emissions for a minimum, average, and maximum space-heating day to demonstrate the contribution of area space heating and cooling demands to the total pollution load.

For this survey, the study area was subdivided into 70 emission zones.

## DATA PROCESSING AND ANALYSIS

### General

Methods of data handling and evaluation were an integral part of the overall project planning. Establishment of data-handling techniques was particularly important in view of the number of agencies involved and the variety of data collected.

Because many thousands of data items would be processed during the project, use of a computer for storage and retrieval was mandatory. Card formats were designed or modified to permit utilization of current Abatement Program computer programs for storage of the project data. In some instances, hand tabulations were necessary to transform the existing data into the required formats.

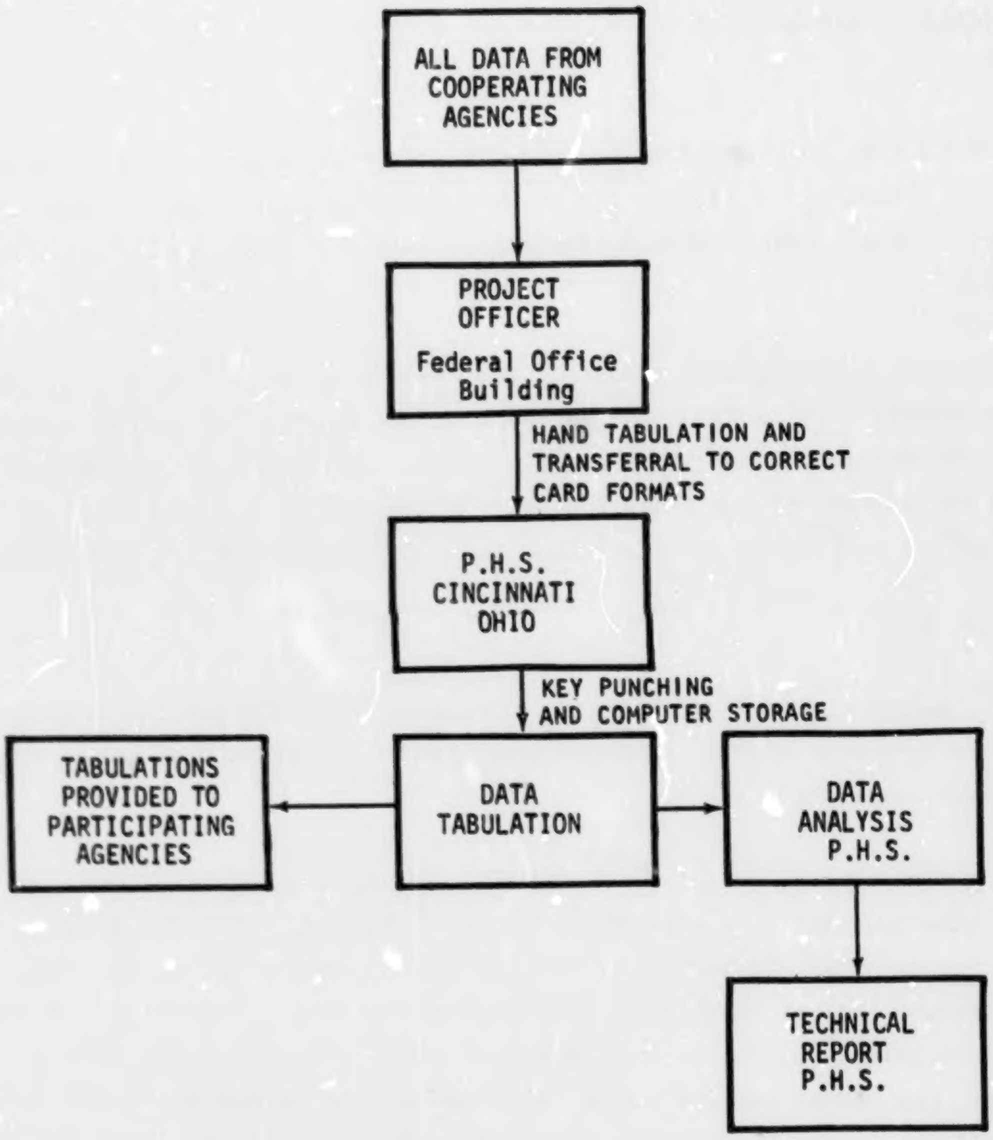
### Air Quality Data

For purposes of this discussion, air quality data are all data obtained through the sampling network, with the exception of meteorological data, which are discussed separately.

The flow diagram (Figure B-1) depicts the major elements of the data process from the time the sample is analyzed and a value recorded until the data are tabulated by the computer and analyzed. All air quality data from the participating agencies flowed through the Project Officer's office at the Federal Office Building. This provided central control to ensure prompt receipt of all data as scheduled. Any manual tabulations or calculations were completed at this time, and the data were then forwarded to Cincinnati, Ohio, for key punching and computer storage. Computer tabulations were compiled for each pollutant by station and time. These tabulations will be supplied to the participating agencies.

### Meteorological Data

The meteorological data were processed in basically the same manner as the air quality data, the main differences being in the reduction procedures. In addition to the data collected at the UMKC Campus and Morse Schools, meteorological data were supplied by the U.S. Weather Bureau at Municipal Airport. These data were processed in the same way as the air quality data.


ALL DATA FROM COOPERATING AGENCIES
PROJECT OFFICER
Federal Office Building
HAND TABULATION AND TRANSFERRAL TO CORRECT CARD FORMATS
P.H.S. CINCINNATI OHIO
KEY PUNCHING AND COMPUTER STORAGE
TABULATIONS PROVIDED TO PARTICIPATING AGENCIES
DATA TABULATION
DATA ANALYSIS P.H.S.
TECHNICAL REPORT P.H.S.

Emissions Inventory Data

Data were gathered for the emissions inventory by means of questionnaires, plant visits, telephone survey, and historical information. These data, because of their nature, were processed differently than the air quality or meteorological data. Detailed description of the emission inventory procedures are given in Appendix D.

Other Data

Additional data related to air pollution effects on the health or welfare of the inhabitants were gathered. These included data on vegetation studies and materials deterioration. These were manually tabulated rather than computerized.

## Data Analysis

The tabulations present the data in formats that permit manual analysis; however, because of the large amount of data collected in this project, computer programs were written or existing programs modified to permit rapid data analysis. The more time-consuming and tedious tasks were given priority for computer programming. For purposes of description, data analysis techniques are divided into two classes; those involving a single pollutant or type of measurement, and those for which two or more pollutants or types of measurements are combined to provide more detailed information than can be obtained with one alone.

## Single-Pollutant Techniques

Averages - Two measures for the average were computed: the arithmetic mean and the geometric mean. The arithmetic mean is the sum of the measurements divided by the number of measurements. The geometric mean is computed by finding the $n^{th}$ root of the product of all the measurements. The geometric mean should be used to represent the data if the measurements are distributed log-normally, which is often the case with air pollution measurements. Computation of the average is important because it permits the use of a single number to represent a large amount of data.

Variability - As with the average, two measures of variability were computed: the standard deviation and the standard geometric deviation. These measures indicate the dispersion among the individual measurements. The standard deviation is used when the underlying distribution of the data is considered normal, whereas the standard geometric deviation is used if the measurements are distributed log-normally.

Frequency Distribution - Frequency distributions show what percent of the total measurements are less than a selected pollutant concentration or measurement level. A computer program performs the analysis and prints the resulting distribution. These distributions are valuable in that comparisons can be made with other data or criteria to determine relative degrees of pollution.

Iso-intensity Maps - Iso-intensity maps were constructed to determine the geographic distribution of specific pollutants over the Abatement Activity area. These maps were drawn by first plotting the average pollutant dosage value for each station. Then areas of dosages within a specified range were determined and grouped into a single zone. The completed map then depicts zones of varying dosage levels throughout the area.

## Combined-Pollutant Techniques

Wind Roses - Wind roses depict the percentage frequencies of wind direction and wind speed. This information is necessary to explain transport of pollutants and to compare present conditions with past data. A computer program provides data for these wind roses.

Pollution Roses - Pollution roses combine meteorological data with pollution concentrations. A completed pollution rose indicates the percent of occurrences of each wind direction that are accompanied by a selected concentration level. Because pollution roses designate both direction and concentration, they can be used to indicate the locations of significant pollutant sources. These may be either point or area sources; however, the pollution rose probably more accurately depicts intensities of emissions from area sources than those from point sources, inasmuch as a small deviation in wind direction may cause emissions from any particular point source to miss a given receptor completely. The wind factor would not be so critical in the case of area emissions. Other factors affect the validity of indications obtained from pollution roses; among these are:

1. The capacity of the air to disperse pollutants; this varies with wind speed, which tends to differ with directions.

2. The height of emissions and distances to sources.

3. The frequency of occurrence of specific wind directions. During some seasons certain wind directions occur infrequently; others, with great frequency. These factors should be considered when interpreting pollution roses.

These analysis techniques provide means of presenting data so that logical interpretations of the results can be made. It is not possible, nor intended, to describe every aspect of data analysis in this report, but only to discuss briefly some of the more general techniques employed by the Public Health Service.

## APPENDIX C. AEROMETRY OPERATION AND TECHNIQUES

### INTRODUCTION

The air monitoring network designed by the Abatement Program, National Center for Air Pollution Control, consisted of semi-automatic continuous samplers, as well as static sampling devices. The project design took into account the ease of access, area background, and area-wide coverage to produce a highly operational and extensive data-gathering network.

### AIR MONITORING NETWORK

The 36 air monitoring stations in the study area were set up and operated as a co-operative effort by the U. S. Public Health Service and the involved agencies. Two stations (Morse School and UMKC Campus) each were equipped with double high-volume filter samplers, sulfur dioxide sequential samplers, AISI filer tape samplers, and complete wind speed and direction measurement systems. Of the remaining two "major" stations in the study area, both (Waterworks and Police Garage) were equipped with double high-volume filter samplers, a sulfur dioxide sequential sampler, and a AISI filter tape sampler. Each of these four stations was also provided a dustfall receptacle and lead sulfation candle either as a part of the Interstate Surveillance Project or as a separate entity. The remaining 32 stations operated by the Public Health Service in conjunction with the various involved local agencies were fully or partially equipped to measure and log air pollution data. Table C-1 lists the air monitoring stations and types of sampling employed at each site. Figure C-1 depicts the locations of the 36 sampling stations.

### SUSPENDED PARTICULATE

Ten Model 2000 H high-volume filter samplers[1] were located in pairs at five of the air monitoring stations in the study area to measure suspended particulate. In addition, 11 single high-volume filter samplers were located at 11 other air monitoring stations. Each double unit was equipped with an electrical timing device on the units for operation from midnight to midnight, on a 24-hour-on, 48-hour-off schedule; thus each pair of samplers sampled 2 days of each 3 day period. The single units were operated in a similar fashion for 1 day, from midnight to midnight of each 3-day period. The days that these single samplers operated coincided with the period of operation for the second sampler in the double units.

Total suspended particulate was collected on 8- by 10-inch glass fiber filters over 24-hour periods. Results were based on differences between the tare weight and final gross weight of each filter and upon the volume of air sampled. Data are reported as micrograms of total particulate per cubic meter of air.

## SULFUR DIOXIDE SEQUENTIAL SAMPLING

Sulfur dioxide sequential samplers were operated at the four major stations. Monitoring for $SO_2$ took place the same 2 out of 3 days as the double high-volume units. Analysis for $SO_2$ was determined by the West-Gaeke technique.[2]

## FILTER TAPES

Four AISI filter tape samplers were operated at the four major stations. These instruments ran continuously and provided 2-hour spots for soiling analyses. The sample tapes were collected periodically and sampling spots were evaluated by percent light transmittance. Levels of contamination are reported in coefficient of haze (Coh) per 1000 lineal feet of air.

## WIND SPEED AND DIRECTION DATA

Wind speed and direction data were obtained at the UMKC Campus and at Morse School. Hourly average wind speed was determined from strip-chart records of wind speed. The "equal area" method was used to extract and tabulate data to the nearest mile per hour. This method is a visual inspection technique by which a value of the wind speed that divides the oscillations of the wind trace into equal areas is selected from each time increment - in this case, 1 hour. The value selected was considered the mean speed for the hour. Speeds of less than 0.5 mile per hour were tabulated as calm. Calms and missing doubtful data were appropriately indicated on tabulations for computer processing. Corrections were applied, if appropriate, for drift of the recording and sensing system from zero.

Hourly average wind direction was determined from record traces of the direction. A representative wind direction was ascertained for each hour by the "equal area" method described above. Calms and missing and doubtful data were appropriately noted on tabulation forms.

## LEAD PEROXIDE SULFATION CANDLES

A lead peroxide sulfation candle network was initiated to determine an index of the activity of $SO_2$ in the atmosphere.

A total of 30 sulfation candle exposure stations were located in the study area. An additional six candles were located at the six Interstate Surveillance Project stations.

The method is based on exposing $PbO_2$ paste in ambient air for 30 days and measuring the sulfation caused by gaseous $SO_2$. After exposure, the material is stripped from the candles with sodium carbonate, and the amount of sulfate is determined by a turbidimetric procedure. The sulfation rate is reported as milligrams of $SO_3$ per 100 square centimeters per day. Correlation studies have shown that multiplying the lead candle value by 0.035 gives an approximation of the average $SO_2$ concentration in ppm for the period of exposure. This factor when applied under applicable conditions permits gross estimates of $SO_2$ values.[2]

DUSTFALL

A network of 30 dustfall receptacles was established to determine the settleable dust rates in the study area. An additional six receptacles were located at the Interstate Surveillance Project.

All samples obtained were analyzed by Public Health Service personnel at the Cincinnati, Ohio, laboratory, after having been exposed for 30 days.

RUBBER CRACKING

A rubber cracking network was initiated to serve as indicators of oxidant concentration in the study area. A total of 10 rubber strip stations were located in the study area. Six more were located at the six Interstate Surveillance Project stations.

The rubber strips were weighted and exposed for 7 days in small shelters. The cracks were then counted and measured in the laboratory.

SPECIAL SAMPLING

Three vegetation exposure chambers were placed at the Waterworks, Police Garage, and Morse School from July 17 through September 5, 1967. In addition, a control chamber with filtered air was operated at the Waterworks. These shelters housed several different plant varieties to obtain relative data on air pollution effects on vegetation. Weekly care for these plants included flushing the pots with distilled water and adding fresh nutrient solution.

Sun photometer measurements were made simultaneously at Municipal Airport, at the New Federal Building, and at the Johnson County Health Department in Olathe, Kansas, during May through November, 1967. These instruments supplied atmospheric turbidity data for each station three times each day.

## INTERSTATE SURVEILLANCE PROJECT

The six Interstate Surveillance Project stations were located throughout the metropolitan complex (Table C-1). These static sampling devices, designated as "effects packages", gather data on dustfall quantity (the amount of large airborne particles), particulate impingement (indicating the direction of the particulate sources), sulfation (an indication of sulfur gases), corrosion and tarnishing of metals, and deterioration of textiles, dyes, and rubber. These data are used as indicators of air quality in the community and as indices of any trends toward increasing or decreasing local air pollution levels.

Table C-1. SAMPLING STATION LOCATIONS AND EQUIPMENT

| Station number | Station location | County | Sampling equipment |
|---|---|---|---|
| 1 | Kansas City, Missouri<br>Kansas City Waterworks<br>North Oak Street & Highway 71 | Clay | A,C,D,F,G,H,I |
| 2 | Kansas City, Missouri<br>Kansas City Municipal Airport | Clay | E |
| 3 | North Kansas City, Missouri<br>Kansas City Municipal Airport on Perimeter | Clay | B,F,G |
| 4 | Kansas City, Kansas<br>Fairfax Airport Control Tower | Wyandotte | B,F,G |
| 5 | Gladstone, Missouri<br>Gladstone Water Department | Clay | F,G |
| 6 | Claycomo, Missouri<br>Claycomo City Hall | Clay | B,F,G,H |
| 7 | Pleasant Valley, Missouri<br>Pleasant Valley City Hall | Clay | F,G |
| 8 | Harrisonville, Missouri<br>C. B. Price Farm | Cass | B,F,G |
| 9 | Kansas City, Missouri<br>Police Garage<br>13th Terrace & Oak | Jackson | A,C,D,I,J |
| 10 | Kansas City, Missouri<br>University of Missouri at Kansas City Campus<br>51st and Troost | Jackson | A,C,D,E,J |
| 11 | Kansas City, Missouri<br>Pleasant Valley School<br>4300 Gardner Road | Jackson | F,G |
| 12 | Kansas City, Missouri<br>Fire Station No. 21<br>Bennington & Independence Roads | Jackson | B,F,G,H |
| 13 | Independence, Missouri<br>Central Independence<br>Thriftway Food Store<br>2300 Liberty (Courtney) | Jackson | F,G,H |
| 14 | Independence, Missouri<br>Independence Health Department | Jackson | A,J |
| 15 | Independence, Missouri<br>South Independence<br>Car Wash<br>U.S. 40 East | Jackson | F,G |

Table C-1 (continued) SAMPLING STATION LOCATIONS AND EQUIPMENT

| Station number | Station location | County | Sampling equipment |
|---|---|---|---|
| 16 | Raytown, Missouri<br>Raytown City Hall<br>63rd Street and Raytown Road | Jackson | F,G |
| 17 | Kansas City, Missouri<br>John Hartman School<br>81st and Oak | Jackson | F,G |
| 18 | Olathe, Kansas<br>Olathe Substation<br>1-1/2 Mile West of<br>Court House on Prairie | Johnson | F,G |
| 19 | Mission, Kansas<br>Hickory Grove School<br>Johnson Drive & Lamar | Johnson | F,G,H |
| 20 | Overland Park, Kansas<br>Dorothy Moody School<br>10101 England Street | Johnson | B,J |
| 21 | North Johnson County, Kansas<br>51st & Renner Road | Johnson | F,G |
| 22 | Kansas City, Kansas<br>Bethel Fire Station<br>81st & Leavenworth Road | Wyandotte | F,G |
| 23 | Kansas City, Kansas<br>East KCK<br>Holiday Inn<br>5th & Minnesota | Wyandotte | B,F,G |
| 24 | Kansas City, Kansas<br>Fire Station No. 14<br>27th & Brickel | Wyandotte | B,F,G,H |
| 25 | Kansas City, Kansas<br>Mark Twain Elementary<br>27th & Minnesota | Wyandotte | F,G |
| 26 | Kansas City, Kansas<br>Wyandotte Swim Club<br>51st & Parallel | Wyandotte | F,G |
| 27 | Kansas City, Kansas<br>Morse School<br>Baltimore & Miami | Wyandotte | A,C,D,E,I,J |
| 28 | Turner, Kansas<br>Turner High School<br>55th & Turner | Wyandotte | F,G,H |
| 29 | Kansas City, Missouri<br>Southeast Elementary<br>N.W. 56th & Norwood Road | Platte | B,F,G,H |

### Table C-1 (continued) SAMPLING STATION LOCATIONS AND EQUIPMENT

| Station number | Station location | County | Sampling equipment |
|---|---|---|---|
| 30 | North Platte County, Missouri<br>Kerrville Water Station No. 4<br>Route 92 & State Road "O" | Platte | B,F,G |
| 31 | Dearborn, Missouri<br>City Limits on State Road "Y" | Platte | F,G |
| 32 | Junction, Missouri<br>Highway 45 & 3-1/2 Miles North on State Road "H" | Platte | F,G |
| 33 | Leavenworth, Kansas<br>521 Delaware | Leavenworth | B,F,G |
| 34 | Sugar Creek, Missouri<br>Sewage Treatment Plant<br>North of America Oil Refinery | Jackson | F,G,H |
| 35 | Independence, Missouri<br>East Independence<br>Richard's United Super<br>17301 E. 24 Highway | Jackson | F,G,H |
| 36 | Independence, Missouri<br>West Independence<br>Morgan's Restaurant<br>308 Blue Ridge Boulevard | Jackson | F,G |
| NA | Kansas City, Kansas<br>Park Department<br>3rd & Richmond | Wyandotte | J |

#### SAMPLING EQUIPMENT LEGEND

A. Suspended particulate - double high-volume samplers
B. Suspended particulate - single high-volume samplers
C. Sulfur dioxide sequential sampler
D. Suspended particulate - AISI filter tape sampler
E. Wind speed and direction equipment
F. Lead peroxide sulfation candle
G. Settleable particulate - dustfall
H. Rubber strip exposure
I. Vegetation exposure
J. Interstate Surveillance Project

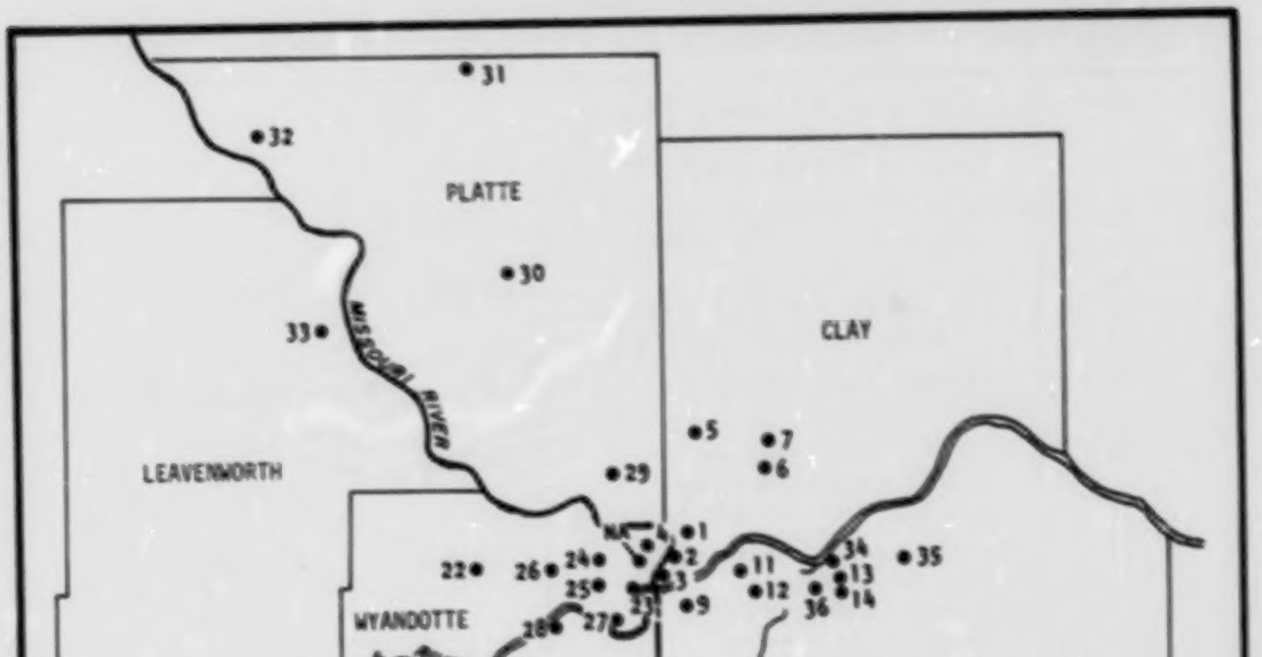

31
32
PLATTE
30
33
MISSOURI RIVER
CLAY
5
7
6
29
LEAVENWORTH
4
1
2
3
22
26
24
25
11
12
34
13
14
35
36
9
WYANDOTTE
28
27
37
KANSAS RIVER
21
19
10
15
16
17
JACKSON
20
18
JOHNSON
BLUE RIVER
KANSAS
MISSOURI
8
CASS

Figure C-1. Kansas City air quality monitoring network.

## APPENDIX C. REFERENCES

1. Jutze, G. A. and K. E. Foster. Recommended standard method for atmospheric sampling of fine particulate by filter media - High-Volume Sampler TR-2- Air Pollution Measurements Committee. J. Air Poll. Cont. Assoc., Volume 17, No. 1 (Jan. 1967).

2. Hochheiser, S. Methods of measuring and monitoring atmospheric sulfur dioxide. PHS Publ. No. 999-AP-6. U. S. Department of Health, Education, and Welfare. Division of Air Pollution. August 1964.

BLANK PAGE

## APPENDIX D. EMISSIONS INVENTORY PROCEDURE

Various means were used to quantify the pollutants (sulfur oxides, particulates, hydrocarbons, and carbon monoxide) released from sources in the study area. Where emissions were of significant magnitude, efforts were made to obtain exact figures, usually by direct interview or mail questionnaire. For the vast number of small sources - automobiles, trucks, medium to small residences, and small industrial, commercial, and governmental establishments - it was not possible to contact each source separately. To obtain accurate figures on the latter categories, it was necessary (1) to employ traffic study data and census figures on population, dwelling units, and manufacturing and commercial operations and (2) to ascertain fuel usage by typical users in the area from local sources and national publications.

The initial data for the report were collected during the 6-month period from February through July 1967. The data collected for the Phase I Kansas City, Kansas - Kansas City, Missouri, Abatement Activity[1] was also used in this report. The Public Health Service rapid survey technique for emission inventories was used.[2] The inventory consisted of evaluating the consumption of gasoline, diesel fuel, coal, fuel oil, and natural gas and of determining emissions from refuse incineration, open burning, process industries, automobile burning, aircraft flights, and evaporative losses. Emissions were determined directly from the fuel input to the equipment for both mobile and stationary sources. Where applicable, control equipment was taken into account for emissions from coal combustion process sources and refuse incineration. Emission factors and average sulfur and ash contents for the general area sources are listed in Table D-1. Emission factors used for both area and point sources were obtained from Public Health Service and New York State publications[3,4,5] and from various Public Health Service staff estimates.

Annual consumption of all fuels, refuse disposal practices, and their emissions and annual process emissions in each zone were determined for the year 1966. These zone emissions were then summed for county, state, and study area totals. Daily emissions were calculated for minimum, average, and maximum space-heating days for sulfur oxides and particulates. Average daily emissions were calculated for hydrocarbons and carbon monoxide. These daily totals were reported as tons of pollutant per square mile and are listed in Table E-1 of Appendix E.

Preceding page blank

## POINT SOURCES

Each residential site, governmental or commercial establishment, industrial site, open-burning dump, etc., from which 100 or more tons of any single pollutant were emitted per year was considered a point source. There were 70 such sources in the study area. Emissions for nearly all point sources were based on data obtained from management officials on their fuel consumption, process losses, refuse disposal practices, and stack tests. Much of the data for the point sources in the Phase I report[1] were used in this presentation.

## MOBILE SOURCES

The principal sources of hydrocarbons and carbon monoxide are from mobile sources. The greatest percentages of these totals, of course, come from the combustion of motor fuel by gasoline- and diesel-powered vehicles.

## GASOLINE AND DIESEL FUEL USAGE

To determine the amount of gasoline used in the area, it was necessary to obtain state-wide gasoline sales.[6] A proportion of these sales for Kansas and Missouri were then distributed to the various counties in the states on the basis of service station sales.[7] It was assumed that the ratio of gasoline sales to total service station sales is constant within the states; thus a direct ratio may be used.

$$\text{Gasoline sales in county} =$$

$$\frac{\text{Service station sales in county (\$)}}{\text{Service station sales in state (\$)}} \times \text{gasoline sales in state (gallons).}$$

It was then estimated that any gasoline sold in a specific county was consumed there, which assumes that the inflow of gasoline into the county equals the outflow.

The amount of gasoline consumed in each zone was a percentage of the county total based on traffic counts, vehicle miles, type of road, and average vehicle speed.[8]

### Table D-1. GENERAL EMISSION FACTORS KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI, STUDY AREA, 1966

(tons/unit[a])

| Source | $SO_x$[b] | Particulates | Hydrocarbons[c] | Carbon monoxide |
|---|---|---|---|---|
| Residual oil | 0.0872[d] | 0.006 | 0.001 | 0.001 |
| Distillate oil | 0.0192[d] | 0.006 | 0.001 | 0.001 |
| Bituminous coal (residential, commercial, governmental) | 0.059[d] | 0.010[e] | 0.005 | 0.025 |
| Bituminous coal (industrial) | 0.059[d] | 0.059[e] | 0.0005 | 0.0015 |
| Natural gas (excluding power plants) | 0.0002 | 0.010 | Negligible | 0.0002 |
| Gasoline (pre-1963 vehicles) | 0.004 | 0.0055 | 0.164 | 1.15 |
| Gasoline (post 1963 vehicles) | 0.004 | 0.0055 | 0.113 | 1.15 |
| Diesel oil | 0.020 | 0.055 | 0.068 | 0.030 |
| Aircraft | f | f | f | f |
| Open-burning dump | 0.0006 | 0.024 | 0.040 | 0.043 |
| Municipal incinerator | 0.001 | g | 0.001 | 0.0005 |
| Residential, industrial commercial, governmental incinerator | 0.0002 | 0.010 | 0.0025 | 0.022 |
| On-site open burning | 0.006 | 0.020 | 0.0725 | 0.030 |
| Automobile burning | Negligible | 0.005 | 0.0015 | 0.0062 |
| Gasoline evaporation (automobile) | - | - | 0.046 | - |
| Gasoline evaporation (handling) | - | - | 0.0135 | - |
| Solvent losses (dry cleaning) | - | - | 1.95 | - |

[a] Fuel oil, gasoline, and diesel oil, 1000 gallons; coal, tons; natural gas, $10^6$ cubic feet; refuse, tons; automobile burning, cars; dry cleaning, 1000 people.

[b] As $SO_2$

[c] As methane

[d] Dependent on sulfur content of fuel; residual oil 1.10% S; distillate oil, 0.24% S; bituminous coal, 3.10% S.

[e] Dependent on ash content of bituminous coal (9.1% A), type of firing unit, and type of control.

[f] Dependent on type of aircraft - see references 3, 4, and 13 of this appendix.

[g] Dependent on type of control - see reference 3 of this appendix.

It was necessary to account for the reduction in blow-by hydrocarbon emissions from automobiles built since 1963. It was assumed that a device installed in all the post-1963 automobiles, controlled blow-by emissions by 80 percent over the pre-1963 automobiles. It was estimated that 41 percent of the cars in the Kansas City study area are post-1963.[28]

The consumption of motor vehicle diesel fuel in the study area is minor by comparison with consumption of gasoline. Motor vehicle diesel fuel sales were available for the States of Kansas and Missouri[6]. This diesel fuel was then proportioned to the counties and emission zones using the same percentages that were used for the gasoline distribution. In addition to the pollutant emissions from the actual operation of a motor vehicle (including evaporative losses from the gas tank and carburetor), there are hydrocarbon losses due to the transfer of gasoline from: (1) storage to tank truck, (2) from tank truck to filling station, and (3) from filling station to motor vehicles tanks. A standard emission factor was applied to the total gasoline sales in the area to account for the hydrocarbon losses listed in Table D-1.

## RAILROAD DIESEL USAGE

Railroad diesel usage was divided into two types: (1) that used by switching diesels in railroad yards and (2) that used by train traffic in and out of the city.

Daily diesel fuel usage for yard traffic was obtained for each yard. If these data were unavailable, the number of switchers working in the yard was obtained, and it was assumed that each of the switchers used 200 gallons of diesel fuel each day.[9] The amount of fuel used in a yard was proportioned into the emission zones by track densities.

The diesel fuel used by train traffic in and out of the city was based on 150 trains per day having an average of three diesel units pulling them with each unit using 100 gallons of diesel fuel each hour when under full load.[9,10] Using these data plus average train speeds and distances traveled, it was assumed that 90,000 gallons per day of railroad diesel fuel was consumed. This fuel usage was then proportioned to emission zones by track densities.

## BARGE DIESEL FUEL USAGE

It was assumed that it takes 0.01 gallon of diesel to push 1 ton of barge 1 mile.[11] Knowing the total tonnage transported on the portion of the Missouri River in the study area during 1966[12] and using the above figure, it was estimated that nearly 26,000 gallons per year of diesel fuel is used per mile of river. Barge diesel fuel usage was then calculated for each emission zone based on river miles in that zone.

## AIRCRAFT

The pollutant emissions from aircraft operations at three major airports in the study area were estimated from data supplied by the Federal Aviation Agency for the year 1966. These data included numbers of takeoffs and landings by the various types of commercial and itinerant planes. Emission factors[3,4,13] were then applied per aircraft flight depending on the type and number of engines on the plane in question.

## PROCESS SOURCES

Emissions from industrial processes (grain milling and handling, asphalt and concrete batch operations, cement manufacture, soap and detergent manufacture, paint and varnish manufacture, fertilizer manufacture, petroleum refining, fiber glass manufacture, ferrous and nonferrous foundries, and other miscellaneous chemical manufacturing) were determined from plant visits and information solicited from company officials. Data obtained on many sources for the Phase I investigation[1] were used for the Phase II inventory with necessary updating of the information. Sources were selected for investigation by type and size of industry from local and national industrial directories. Included in this category are the hydrocarbon emissions from evaporative losses, such as from dry cleaning and solvent operations and printing establishments. In most cases process emissions were estimated by Public Health Service engineers since no stack data or company estimates were available from plant officials.

## REFUSE DISPOSAL

The amount of refuse disposed of in the study area was estimated on the basis of information gained from local officials, and supervisory personnel at landfills, open-burning dumps, auto-burning sites, and on-site commercial, governmental, industrial, and residential incinerators.

The above surveyed types of disposal accounted for the greater part of the estimated refuse generated in the study area (1660 pounds per capita per year).[14,27] The difference between the refuse surveyed and that assumed to be generated in the study area was estimated to be on-site incineration and open-burning.

To allow for that part of the refuse that is not combustible, it was assumed that 40 percent of the difference in rural areas is open burned either in burning barrels or openly on the ground. In urban areas 10 percent of the difference was assumed to be incinerated in single-chamber incinerators and 20 percent open burned. Emission calculations on surveyed refuse disposal practices took into account type of disposal and control equipment.

## COMBUSTION FUELS BURNED AT STATIONARY SOURCES

Sources were delineated in terms of fuel type and user types to determine the quantity of the various combustion fuels burned during different times of the year. Bituminous coal, coke, distillate and residual oil, natural gas, and refinery gas are the only fuels used in significant quantities in the study area. Fuel sources were listed as residential, commercial and governmental, industrial and steam-electric power plants. Residential sources included all dwellings from one-family homes to multistory high-rise apartment buildings.

The portions of fuel burned for space-heating and that burned on a steady day-to-day basis throughout the year were determined. Essentially, all commercial, much residential, and some industrial fuel were burned for space-heating purposes. The type and quantity of fuel used at the steam-electric power plants varies with the time of year based on the interruptible status of natural gas and the electric load requirements. The operating characteristics of each plant were taken into account in the calculation of daily emissions. The variable use of fuel for space heating determines the differences in emissions on minimum, average, and maximum space-heating days.

The fuel totals for the study area broken down by county were determined by various methods depending on the fuel type and source category. Overall study area fuel totals were obtained from data supplied by various local fuel dealers, natural gas suppliers,[15] local public utility officials,[16] and national and local publications.[17,18,19,20]

## RESIDENTIAL FUEL USAGE

Fuels consumed by residential sources were determined from information available on population, dwelling units, and the relative use of coal, oil, and natural gas.[21,22] Smaller residential units were assumed to use natural gas, distillate oil, or bituminous coal for heating. Larger apartment buildings, i.e. 50 units or more, that used oil were assumed to use residual oil.

## POPULATION AND DWELLING UNITS

Census data from 1964 for the counties and most of the census tracts in the study area were listed in a Kansas City, Missouri planning department publication.[23] Along with this data and the 1960 census and dwelling unit data[21,22,24] it was possible to estimate 1966 population and dwelling units by census tract. The census tract data was then transferred to the emission zones.

Dwelling units built since 1960 were assumed to use either natural gas or electric heat. It was determined that 98 percent of these new dwelling units had natural gas as a heating fuel while only 2 percent had electric heat. Wherever there had been a decrease in dwelling units since 1960 due to demolition and urban renewal, a proportioned decrease in dwelling units using coal or oil was made. This was done since most of these units that are razed are older buildings, which tend to burn the dirtier fuels.

## RESIDENTIAL USE OF COAL

The number of area-wide occupied dwelling units using coal in 1960 was developed using Bureau of the Census data.[22] These data list by county and large cities those dwelling units using coal for heating purposes. It was estimated that the dwelling units using coal in 1960 still used coal in 1966, except in those areas where there was urban renewal and the old coal-burning buildings had been torn down.

Based on degree-days and rooms per unit, the amount of coal per dwelling unit used for heating purposes in various subdivisions of the study area is shown in Table D-2. It was assumed that all coal used residentially was only for space-heating.

## RESIDENTIAL USE OF FUEL OIL

The number of 1960 and 1966 area-wide dwelling units burning fuel oil for heat was determined in the same manner as the number burning coal. Residential structures of more than 50 dwelling units that use fuel oil were assumed to use residual oil. From data in the 1960 Census of Housing,[22] it was possible to estimate the total number of dwelling units in structures of 50 or more units.

Table D-2 lists the estimated fuel oil used by an average dwelling unit using fuel oil for heating. It was determined from census data[22] that very little fuel oil in the Kansas City area is used for cooking and hot water heating; thus it was assumed that essentially all residential fuel oil was used for space-heating.

## RESIDENTIAL USE OF NATURAL GAS

The number of dwelling units in 1960 using natural gas for heating purposes was determined from the 1960 census in the same manner as that described for coal and fuel oil. Updating these data to 1966 was accomplished by adding to the 1960 figures 98 percent of the new dwelling units built since 1960.

Table D-2 lists the estimated natural gas used by a residential dwelling unit using natural gas for heating. Actual usage totals furnished by natural gas suppliers[15] for each county in the study area indicated larger overall figures than can be estimated from the data listed in Table D-2. These larger figures reflect the natural gas used for water heating and cooking, not only in the natural-gas-heated homes, but also in those homes heated with coal or oil. This differential amount of gas was allotted to the emission zones in proportion to the number of dwelling units using gas for heating. This estimate can be made since there is probably a reasonably equal distribution of both types of natural-gas users in the emission zones.

## COMMERCIAL AND GOVERNMENTAL FUEL USE

Federal, state, and local governmental agencies and large private institutions were surveyed through interviews, questionnaires, and information from local fuel dealers and natural gas suppliers.[15] The fuel data and control equipment information obtained from these known sources were used to estimate their emissions and to determine whether they should be considered as point sources. These fuel-use data and the resulting emissions were placed in the emission zones corresponding to the location of the source in question.

The homogeneous coal and oil usage by commercial and governmental establishments was determined as the difference between estimated totals for each county and the surveyed fuel as listed above. The commercial and governmental coal and oil totals for each county were estimated from Bureau of Mines data for Kansas and Missouri.[17,18] The estimates for each county were based on a population and

Table D-2. AVERAGE SPACE-HEATING FUEL USAGE FOR RESIDENTIAL DWELLING UNITS

| Area | Coal, (tons/year) | Oil, (gallons/year) | Natural gas, ($ft^3$/year) |
|---|---|---|---|
| Independence, Missouri | 5.4 | 815 | 101,700 |
| Kansas City, Missouri | 5.1 | 760 | 95,500 |
| Kansas City, Kansas | 5.3 | 800 | 99,700 |
| Cass County | 5.4 | 815 | 101,700 |
| Clay County (Urban, other than Kansas City) | 5.6 | 850 | 105,900 |
| Clay County (Rural) | 5.4 | 815 | 101,700 |
| Jackson County (Urban, other than Kansas City or Independence) | 5.6 | 850 | 105,900 |
| Jackson County (Rural) | 5.4 | 815 | 101,700 |
| Platte County (Rural) | 5.4 | 815 | 101,700 |
| Leavenworth County | 5.3 | 800 | 99,700 |
| Johnson County (Urban, other than Kansas City) | 6.0 | 900 | 112,100 |
| Johnson County (Rural) | 5.6 | 850 | 105,900 |
| Wyandotte County (Urban, other than Kansas City) | 6.0 | 900 | 112,100 |
| Wyandotte County (Rural) | 5.6 | 850 | 105,900 |

commercial proportioning basis.[25] The surveyed coal and oil were then subtracted from the overall totals, and the difference was apportioned to the emission zones based on knowledge of the area, U. S. Geological Survey topographical maps, land-use maps, and information obtained from local officials. Natural gas data were supplied by gas utilities[15] and apportioned in the same manner.

## INDUSTRIAL FUEL USE

Industrial users considered to be possible point sources were contacted. The fuel data, along with their process and refuse emissions, were used to determine whether they would be considered point sources. The emissions and fuel data were placed in the proper emission zone corresponding to the location of the plant in question.

It was also necessary to estimate the amount of fuel used by the smaller industrial sources not surveyed. State-wide data for industrial use of oil and coal in Kansas and Missouri were obtained from Bureau of Mines[18] and Census Bureau[20] publications. These data were then proportioned to the counties of the study area according to the number of manufacturing employees.[26] Natural-gas usage by industrial consumers was obtained from the gas utilities.[15] In each county the surveyed industrial fuel data were subtracted from the estimates for the total county. The remaining homogeneous background industrial fuel figure was then distributed over the emission zones within the county in proportion to the degree of industrialization. U. S. Geological Survey topographical maps, land-use maps, and knowledge of the area were used to estimate the degree of industrialization in each zone.

## STEAM-ELECTRIC POWER PLANTS

Fuel-use figures were obtained directly from the utilities in the study area.[16] Amounts of fuel oil, bituminous coal, and natural gas used at all power-generating stations were provided together with sulfur and ash contents, type of firing units, control equipment and seasonal variation in operation characteristics.

## DAILY VARIATIONS IN POLLUTANTS RESULTING FROM SPACE-HEATING

Sulfur oxides and particulate emissions were determined for minimum, average, and maximum space-heating days to show the variation in emission rates due to increased fuel usage on heating days in the fall, spring, and winter. For each zone, the emissions were divided into a variable fraction resulting from space-heating and a steady fraction resulting from operations that are essentially constant throughout the year. The variable emissions were assumed to consist of:

1. All commercial and governmental fuel combustion emissions.
2. 25 percent of the industrial fuel emissions.
3. A portion of the residential fuel emissions (see previous section on residential fuel burning.
4. Emissions from steam electric power plants (variable because of differences in electric loads and the interruptible status of gas usage, which are dependent on seasons of the year).

Steady day-to-day emissions consist of:

1. All process emissions.
2. 75 percent of the industrial fuel emissions.
3. A portion of the residential fuel emissions, i.e., those emanating from cooking and water heating (see previous section on residential fuel burning).
4. All refuse disposal emissions.
5. All mobile source emissions.

On a minimum heating day, it was assumed that there was no space-heating; therefore, emissions are represented by the above-mentioned steady pollutant figures. Average and maximum space-heating day totals were determined by adding steady emissions to variable emissions during respective days. Meteorological data acquired from the U. S. Weather Bureau were used to determine these fractions of the yearly variable pollutants emitted during average and maximum space-heating days. The following formulas were used to calculate daily sulfur oxides and particulate emissions.

Minimum day = steady emissions, tons per day
Average day = minimum day + variable emissions (tons/year)(21/4614)
Maximum day = minimum day + variavle emissions (tons/year)(56/4614)

The factor 21/4614 represents the fraction of annual degree-days occurring on the average heating day. The value 21 is the mean degree-days for all days of the year with average temperatures less than 65°F, the value 4,614 is the cumulative degree-days for the year 1966. The factor 56/4614 represents the fraction of annual degree-days occurring on coldest days; the value 56 is the normalized average degree-days for the 4 coldest days of the year. Daily tonnages were divided by the zone areas to yield emission densities in terms of tons of emissions per square mile.

Carbon monoxide and hydrocarbon emission densities were only calculated for an average day, since the greatest portion of these emissions are steady throughout the year. The variation in fuel usage due to space heating has very little effect on these emissions since their emissions rates from fuel combustion are small.

# APPENDIX D. REFERENCES

1. Kansas City, Kansas - Kansas City, Missouri Air Pollution Abatement Activity, USDHEW, PHS, NCAPC, Cincinnati, Ohio. January 1967.

2. Rapid survey technique for estimating community air pollution emissions. Public Health Service Publication No. 999-AP-29, Environmental Health Series. USDHEW, NCAPC, Cincinnati, Ohio. October 1966.

3. Mayer, M. A compilation of air pollution emissions factors for combustion processes, gasoline evaporation, and selected industrial processes. USDHEW, PHS, DAP, TAB, Cincinnati, Ohio. May 1965.

4. Duprey, R. L. Compilation of air pollutant emission factors. USDHEW, PHS, NCAPC, ACP, Cincinnati, Ohio. 1967 (unpublished).

5. Procedure for conducting comprehensive air pollution surveys. New York State Department of Health, Bureau of Air Pollution Control Services. Albany, New York. August 18, 1965.

6. Analysis of motor-fuel usage in calendar year 1966. Tables MF-21 and MF-25. U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads. June 1967.

7. U. S. Department of Commerce. Census of Business, Retail Trade, Kansas and Missouri. 1963.

8. McMichael, W. F. and Rose, Jr. A. H. A comparison of automotive emissions in cities at low and high altitudes. USDHEW, DAP, Robert A. Taft Sanitary Engineering Center. Presented at APCA meeting, Toronto, Canada. June 1965.

9. Private communication: Union Pacific Railroad.

10. Private communication: Kansas City Terminal Railroad.

11. Private communication: Sioux City-New Orleans Barge Lines.

12. Summary of Missouri River Navigation. U. S. Army, Corps of Engineers.

13. Lozano, E. R., et.al. Air pollution emissions from jet engines. Presented at the APCA meeting, Cleveland, Ohio. June 1967.

14. Municipal Refuse Disposal. American Public Works Association. Chicago, Ill. 1966.

15. Personal communications:
Cities Service Gas Company
Kansas Power and Light Company
Greeley Gas Company
Gas Service Company
Associated Natural Gas Company
Union Gas System, Inc.

16. Personal communication:
Missouri Public Service Company
Northwest Electric Corporation
Kansas City Power and Light
Independence Power and Light
Board of Public Utilities

17. Bituminous coal and lignite distribution, calendar year 1965. Bituminous Coal and Lignite Distribution Quarterly. U. S. Department of Interior, Bureau of Mines. March 1966.

18. Shipments of fuel oil and kerosene in 1965. Fuel Oil Shipments Annual. U. S. Department of Interior, Bureau of Mines. August 9, 1966.

19. Minerals Yearbook. Volume II, 1962 and 1964. U. S. Department of Interior, Bureau of Mines.

20. Fuels and electric energy consumed in manufacturing industries. 1962. U. S. Department of Commerce. 1963 Census of Manufacturers MC 63(1)-7.

21. U. S. Bureau of Census. Census of population and housing, PHC(1)-70. U. S. Department of Commerce. Washington, D. C. 1960.

22. U. S. Bureau of Census. Census of housing, Missouri and Kansas, HC(1)-27 and HC(1)-18. U. S. Department of Commerce, Washington, D. C. 1960.

23. Population, Kansas City Studies 1964-1190. Community renewal report No. 1. City Planning Department. Kansas City, Missouri. December 1964.

24. U. S. Bureau of Census. Census of population, general population characteristics, Missouri and Kansas. PC(1)-27B and PC(1)-18B. U. S. Department of Commerce. Washington, D. C. 1960.

25. U. S. Bureau of Census. Census of business, retail and wholesale trade for Kansas and Missouri. U. S. Department of Commerce. Washington, D. C. 1963.

26. U. S. Bureau of Census. Census of manufacturing area reports, Kansas and Missouri. U. S. Department of Commerce. Washington, D. C. 1963.

27. Kaiser, E. R. Chemical analysis of refuse components. 1966 National Incinerator Conference.

28. 1967 Automobile facts and figures. Automobile Manufacturers Association, Inc. Detroit, Michigan.

## APPENDIX E. POLLUTANT MEASUREMENT DATA

This appendix contains tables and figures pertinent to the Technical Report. Included are the following:

1. Emission inventory zone map.
2. Emission densities for pollutants by counties in study area.
3. Frequency distribution of suspended particulates (high-volume samplers) data.
4. Frequency distributions of suspended particulates (AISI soiling index samplers) data.
5. Frequency distributions of sulfur dioxide data.

**Preceding page blank**

BLANK PAGE

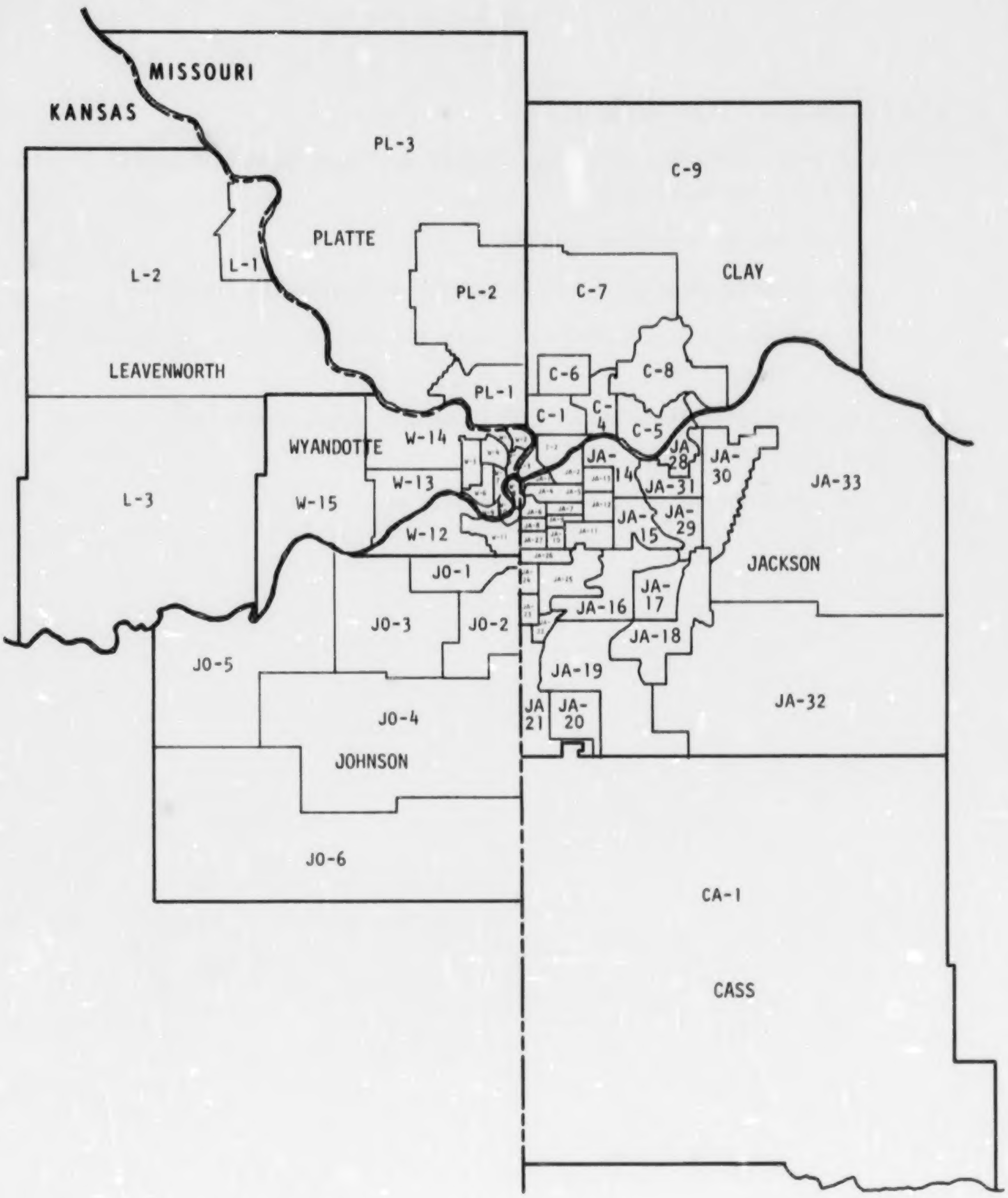

MISSOURI
KANSAS
PL-3
C-9
PLATTE
L-1
L-2
PL-2
C-7
CLAY
C-8
LEAVENWORTH
C-6
PL-1
C-1
C-4
C-5
WYANDOTTE
W-14
JA-14
JA-28
JA-30
JA-33
W-13
JA-31
L-3
W-15
JA-15
JA-29
W-12
JACKSON
JO-1
JA-17
JA-16
JO-3
JO-2
JA-18
JO-5
JA-19
JA-32
JO-4
JA-21
JA-20
JOHNSON
JO-6
CA-1
CASS

Figure E-1. Emissions inventory zone map for Kansas City study area.

## Table E-1. EMISSION DENSITIES FOR COUNTIES KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI STUDY AREA, 1966

(tons/mi$^2$-day)

| Emission zone | Area mi$^2$ | Sulfur oxides space-heating days | | | Particulates space-heating days | | | Hydrocarbons average day | Carbon monoxide average day |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Avg | Max | Min | Avg | Max | | |
| Cass | | | | | | | | | |
| CA-1 | 698.0 | Neg | Neg. | Neg. | Neg. | Neg. | Neg. | Neg. | 0.1 |
| Clay | | | | | | | | | |
| C-1 | 10.3 | Neg | 0.1 | 0.3 | 0.1 | 0.1 | 0.2 | 0.4 | 1.7 |
| C-2 | 4.6 | 0.6 | 1.5 | 3.0 | 2.4 | 3.2 | 4.5 | 2.1 | 6.5 |
| C-3 | 1.9 | Neg | Neg | Neg | Neg | Neg | Neg | 1.5 | 4.4 |
| C-4 | 8.7 | Neg | 0.1 | 0.2 | Neg | 0.1 | 0.1 | 0.3 | 1.4 |
| C-5 | 17.8 | Neg | Neg | Neg | Neg | Neg | 0.1 | 0.1 | 0.4 |
| C-6 | 7.2 | Neg | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.4 | 1.7 |
| C-7 | 51.0 | Neg | Neg | Neg | Neg | Neg | Neg | Neg | 0.2 |
| C-8 | 26.5 | Neg | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.6 | 0.9 |
| C-9 | 278.0 | Neg | Neg. | Neg | Neg | Neg | Neg | Neg | 0.2 |
| Jackson | | | | | | | | | |
| JA-1 | 0.9 | 0.6 | 12.2 | 30.4 | 0.9 | 3.8 | 7.9 | 7.1 | 31.6 |
| JA-2 | 2.8 | 0.1 | 0.2 | 0.5 | 1.4 | 1.5 | 1.6 | 2.2 | 10.0 |
| JA-3 | 1.2 | 0.5 | 1.2 | 2.4 | 0.8 | 1.2 | 2.1 | 4.3 | 17.8 |
| JA-4 | 1.8 | 0.4 | 1.5 | 3.3 | 0.7 | 1.3 | 2.3 | 4.9 | 19.8 |
| JA-5 | 1.3 | 0.1 | 0.8 | 2.2 | 0.3 | 0.5 | 0.8 | 4.3 | 21.6 |
| JA-6 | 2.8 | 0.4 | 1.3 | 2.8 | 0.8 | 1.4 | 2.3 | 3.8 | 12.8 |

Table E-1.(continued). EMISSION DENSITIES FOR COUNTIES
KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI,
STUDY AREA, 1966

(tons/mi$^2$-day)

| Emission zone | Area mi$^2$ | Sulfur oxides space-heating days | | | Particulates space-heating days | | | Hydrocarbons average day | Carbon monoxide average day |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Avg | Max | Min | Avg | Max | | |
| JA-7 | 1.4 | 0.2 | 1.4 | 3.2 | Neg. | 0.8 | 1.4 | 4.4 | 20.1 |
| JA-8 | 2.0 | 0.2 | 0.8 | 2.0 | 0.3 | 0.6 | 1.0 | 3.3 | 14.1 |
| JA-9 | 1.3 | 0.1 | 0.5 | 1.2 | 0.3 | 0.5 | 0.7 | 4.3 | 21.6 |
| JA-10 | 1.4 | 0.1 | 0.6 | 1.4 | 0.4 | 0.5 | 0.7 | 4.1 | 20.1 |
| JA-11 | 3.8 | 0.1 | 0.7 | 1.8 | 0.2 | 0.4 | 0.7 | 1.7 | 7.5 |
| JA-12 | 2.7 | 0.1 | 0.6 | 1.3 | 0.2 | 0.4 | 0.7 | 2.3 | 10.4 |
| JA-13 | 2.2 | 0.1 | 0.6 | 1.5 | 0.4 | 0.6 | 1.0 | 2.8 | 12.8 |
| JA-14 | 11.7 | 0.4 | 5.0 | 11.8 | 1.4 | 1.7 | 2.0 | 2.0 | 3.4 |
| JA-15 | 8.4 | 0.2 | 0.4 | 0.8 | 0.5 | 0.6 | 0.8 | 3.3 | 3.6 |
| JA-16 | 15.0 | Neg | Neg | 0.1 | Neg | 0.1 | 0.1 | 0.2 | 1.0 |
| JA-17 | 9.7 | Neg | 0.2 | 0.4 | 0.1 | 0.2 | 0.2 | 0.6 | 2.3 |
| JA-18 | 25.0 | Neg | Neg | Neg | Neg | Neg | Neg | 0.1 | 3.4 |
| JA-19 | 29.3 | Neg | Neg | Neg | Neg | Neg | Neg | 0.2 | 0.7 |
| JA-20 | 9.4 | Neg | 0.1 | 0.3 | 0.1 | 0.1 | 0.2 | 0.5 | 1.5 |
| JA-21 | 22.6 | Neg | Neg | Neg | Neg | Neg | Neg | 0.1 | 0.3 |
| JA-22 | 3.6 | 0.1 | 0.5 | 1.2 | 0.8 | 0.9 | 1.2 | 1.9 | 6.6 |
| JA-23 | 3.1 | Neg | 0.3 | 0.8 | 0.2 | 0.3 | 0.4 | 1.6 | 7.0 |
| JA-24 | 3.4 | Neg | 0.3 | 0.8 | 0.1 | 0.2 | 0.3 | 1.8 | 8.3 |
| JA-25 | 6.6 | Neg | 0.3 | 0.8 | 0.2 | 0.3 | 0.5 | 1.1 | 4.3 |
| JA-26 | 3.5 | Neg | 0.4 | 0.9 | 0.2 | 0.3 | 0.4 | 2.1 | 10.3 |

Table E-1 (continued). EMISSION DENSITIES FOR COUNTIES
KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI,
STUDY AREA, 1966
(tons/mi$^2$-day)

| Emission zone | Area mi$^2$ | Sulfur oxides space-heating days | | | Particulates space-heating days | | | Hydrocarbons average day | Carbon monoxide average day |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Avg | Max | Min | Avg | Max | | |
| JA-27 | 1.9 | 0.2 | 0.8 | 2.0 | Neg | 0.8 | 1.3 | 3.1 | 11.5 |
| JA-28 | 4.6 | 10.5 | 12.1 | 15.1 | 2.3 | 2.6 | 3.0 | 11.3 | 6.0 |
| JA-29 | 8.0 | Neg | 0.1 | 0.3 | 0.1 | 0.1 | 0.2 | 0.8 | 3.6 |
| JA-30 | 32.8 | Neg | 0.3 | 0.8 | 0.1 | 0.1 | 0.2 | 0.1 | 0.7 |
| JA-31 | 7.5 | 0.1 | 0.3 | 0.7 | 0.2 | 0.3 | 0.5 | 1.2 | 4.8 |
| JA-32 | 159.0 | Neg | Neg | Neg | Neg | Neg | Neg | Neg | Neg |
| JA-33 | 218.0 | 0.3 | 0.3 | 0.4 | Neg | Neg | Neg | Neg | Neg |
| Platte | | | | | | | | | |
| PL-1 | 19.8 | Neg | Neg | Neg | Neg | Neg | Neg | 0.2 | 0.7 |
| PL-2 | 63.5 | Neg | Neg | Neg | Neg | Neg | Neg | 0.1 | 0.3 |
| PL-3 | 335.0 | Neg | Neg | Neg | Neg | Neg | Neg | Neg | Neg |
| Johnson | | | | | | | | | |
| JO-1 | 10.8 | Neg | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.8 | 3.7 |
| JO-2 | 20.0 | Neg | Neg | 0.1 | Neg | 0.1 | 0.1 | 0.4 | 2.0 |
| JO-3 | 51.0 | Neg | Neg | Neg | 0.5 | 0.5 | 0.5 | 0.7 | 1.4 |
| JO-4 | 127.2 | Neg | Neg | Neg | Neg | Neg | Neg | 0.1 | 0.3 |
| JO-5 | 99.5 | Neg | 0.1 | 0.4 | Neg | 0.1 | 0.3 | 0.1 | 0.3 |
| JO-6 | 168.0 | Neg | Neg | Neg | Neg | Neg | Neg | Neg | 0.1 |

Table E-1 (continued). EMISSION DENSITIES FOR COUNTIES
KANSAS CITY, KANSAS - KANSAS CITY, MISSOURI,
STUDY AREA, 1966
(tons/mi$^2$-day)

| Emission zone | Area mi$^2$ | Sulfur oxides space-heating days | | | Particulates space-heating days | | | Hydrocarbons average day | Carbon monoxide average day |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Avg | Max | Min | Avg | Max | | |
| Leavenworth | | | | | | | | | |
| L-1 | 18.2 | Neg | 0.1 | 0.2 | 0.1 | 0.3 | 0.3 | 0.8 | 3.7 |
| L-2 | 219.6 | Neg | Neg | Neg | Neg | Neg | Neg | Neg | 0.1 |
| L-3 | 229.0 | Neg | Neg | Neg | Neg | Neg | Neg | Neg | 0.1 |
| Wyandotte | | | | | | | | | |
| W-1 | 1.7 | Neg | 13.8 | 31.3 | 5.1 | 8.3 | 12.1 | 15.2 | 26.4 |
| W-2 | 1.4 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 3.3 | 12.9 |
| W-3 | 3.6 | 0.1 | 0.2 | 0.4 | 0.1 | 0.2 | 0.2 | 2.3 | 12.5 |
| W-4 | 2.4 | 0.2 | 0.5 | 1.0 | 0.3 | 0.5 | 0.7 | 4.1 | 18.8 |
| W-5 | 1.0 | 61.1 | 72.5 | 91.7 | 4.1 | 5.5 | 7.8 | 27.9 | 44.9 |
| W-6 | 2.6 | 0.2 | 0.5 | 1.0 | 0.2 | 0.4 | 0.7 | 4.4 | 21.7 |
| W-7 | 1.9 | Neg | 0.8 | 1.6 | Neg | 0.7 | 1.2 | 6.4 | 29.7 |
| W-8 | 0.7 | 0.7 | 1.3 | 2.4 | 5.7 | 6.1 | 6.8 | 13.9 | 64.0 |
| W-9 | 2.7 | 0.6 | 10.7 | 23.8 | 1.2 | 2.9 | 5.4 | 5.9 | 21.6 |
| W-10 | 1.8 | Neg | 0.8 | 1.5 | 2.1 | 2.4 | 2.8 | 8.4 | 31.3 |
| W-11 | 4.2 | 0.1 | 0.3 | 0.6 | 0.2 | 0.3 | 0.5 | 3.5 | 13.4 |
| W-12 | 17.2 | Neg | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 0.6 | 26.2 |
| W-13 | 12.8 | Neg | Neg | 0.1 | 0.2 | 0.2 | 0.2 | 0.4 | 1.8 |
| W-14 | 23.4 | Neg | Neg | Neg | Neg | Neg | Neg | 0.4 | 0.9 |
| W-15 | 69.5 | Neg | Neg | Neg | 0.2 | 0.2 | 0.2 | 0.1 | 0.3 |

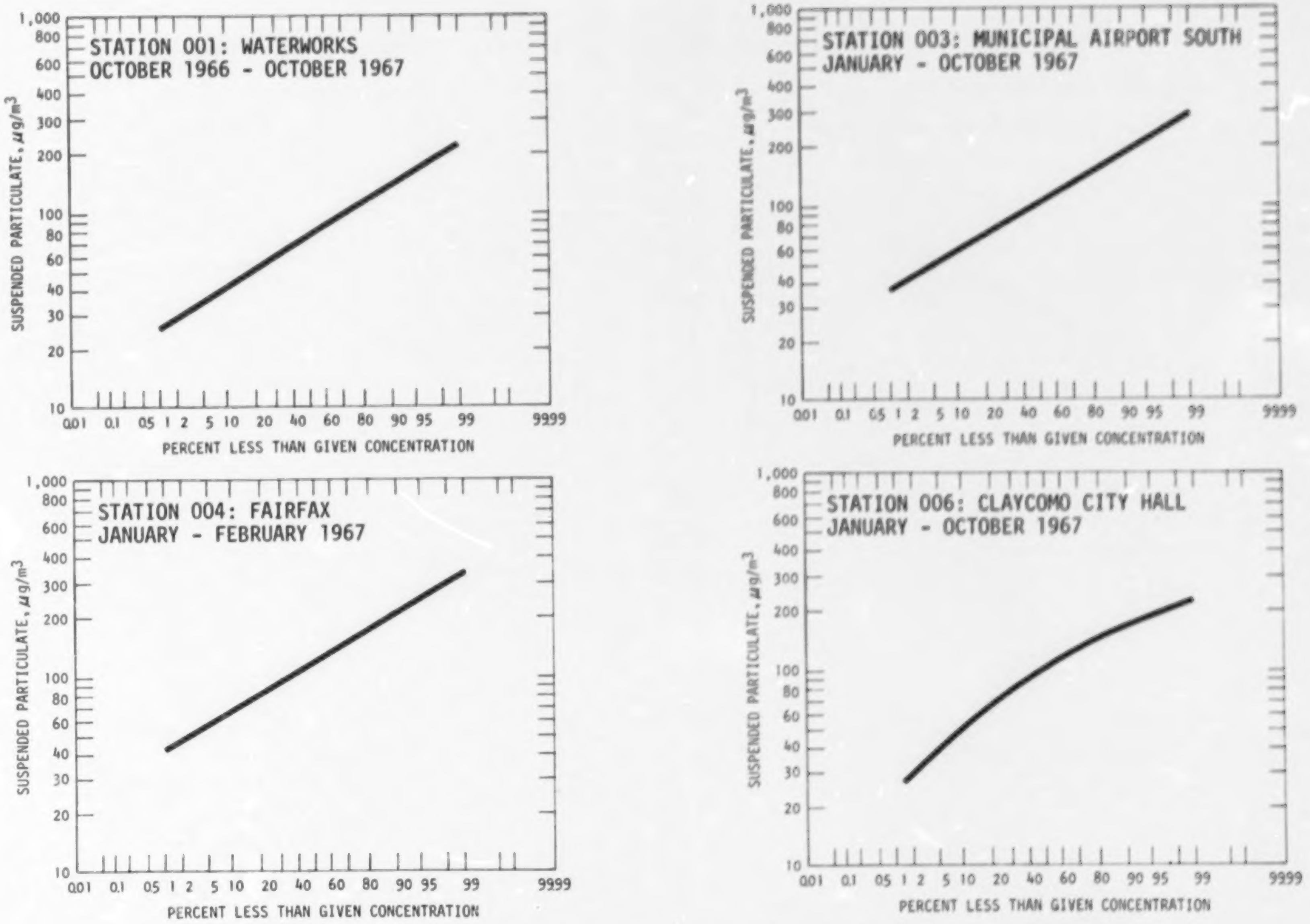


Figure E-2. Frequency distributions of suspended particulates - by high-volume samplers - for stations 001, 003, 004, and 006.

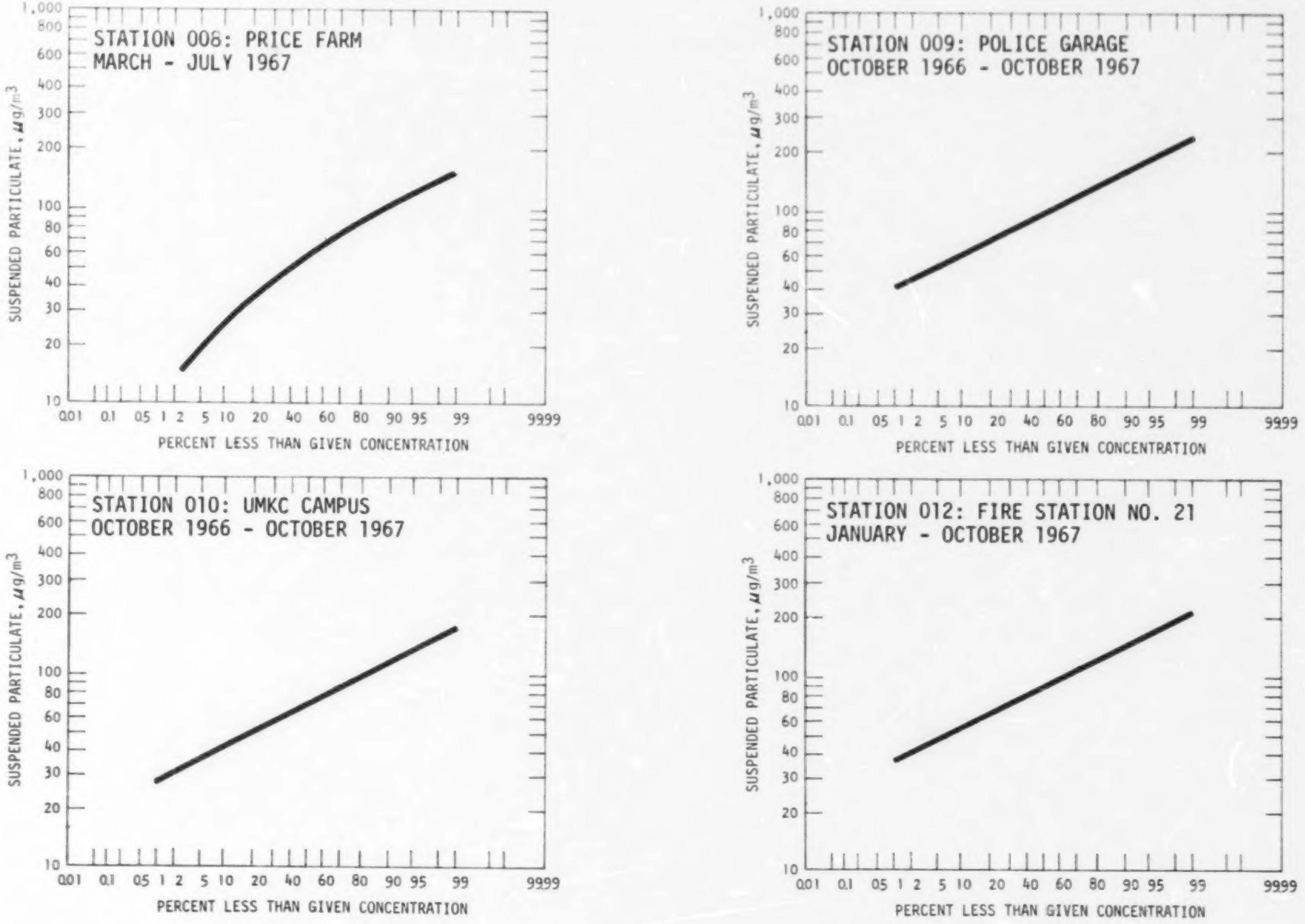


Figure E-3. Frequency distributions of suspended particulates - by high-volume samplers - for stations 008, 009, 010, and 012.

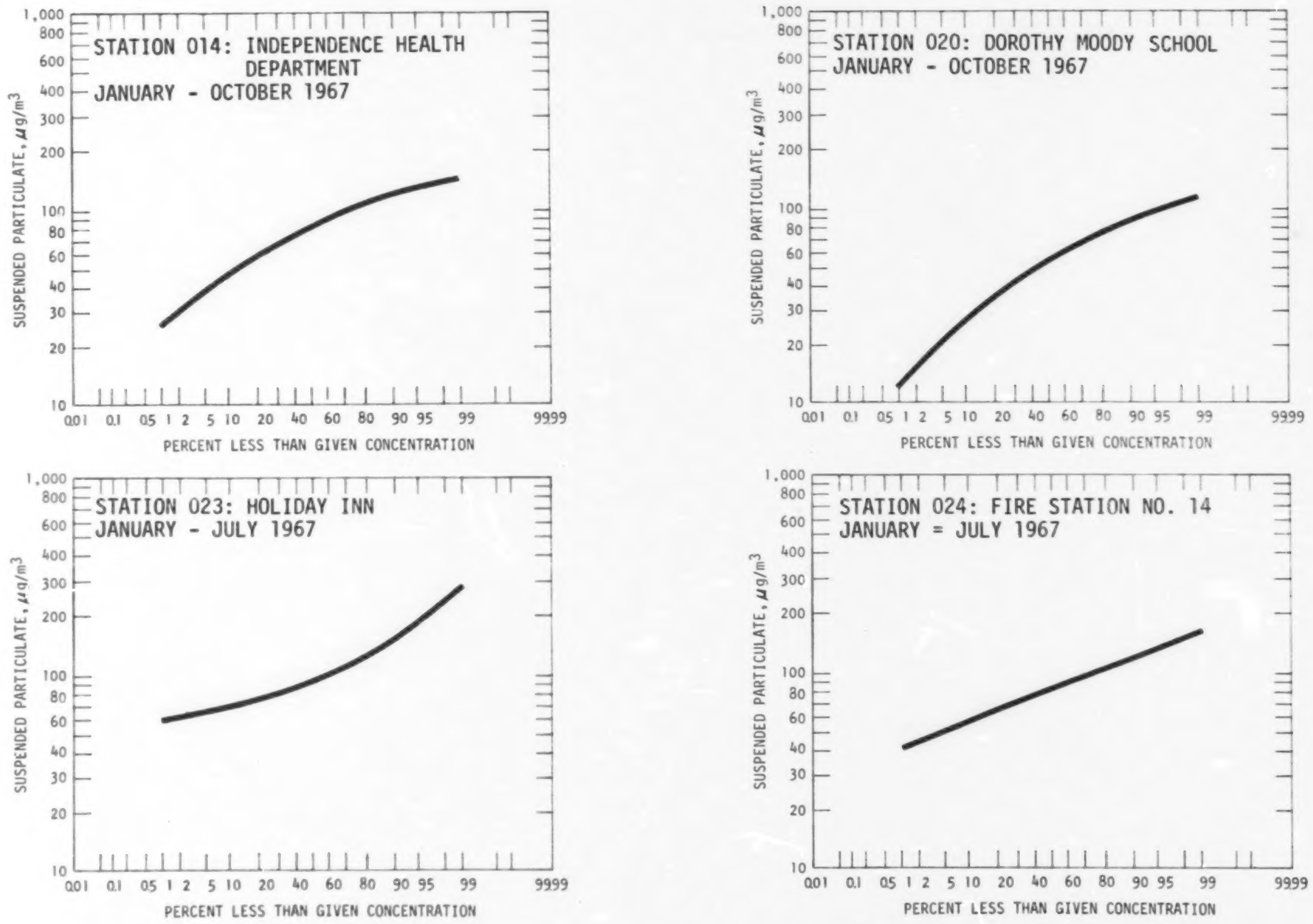


**Figure E-4.** Frequency distributions of suspended particulates - by high-volume samplers - for stations 014, 020, 023, and 024.

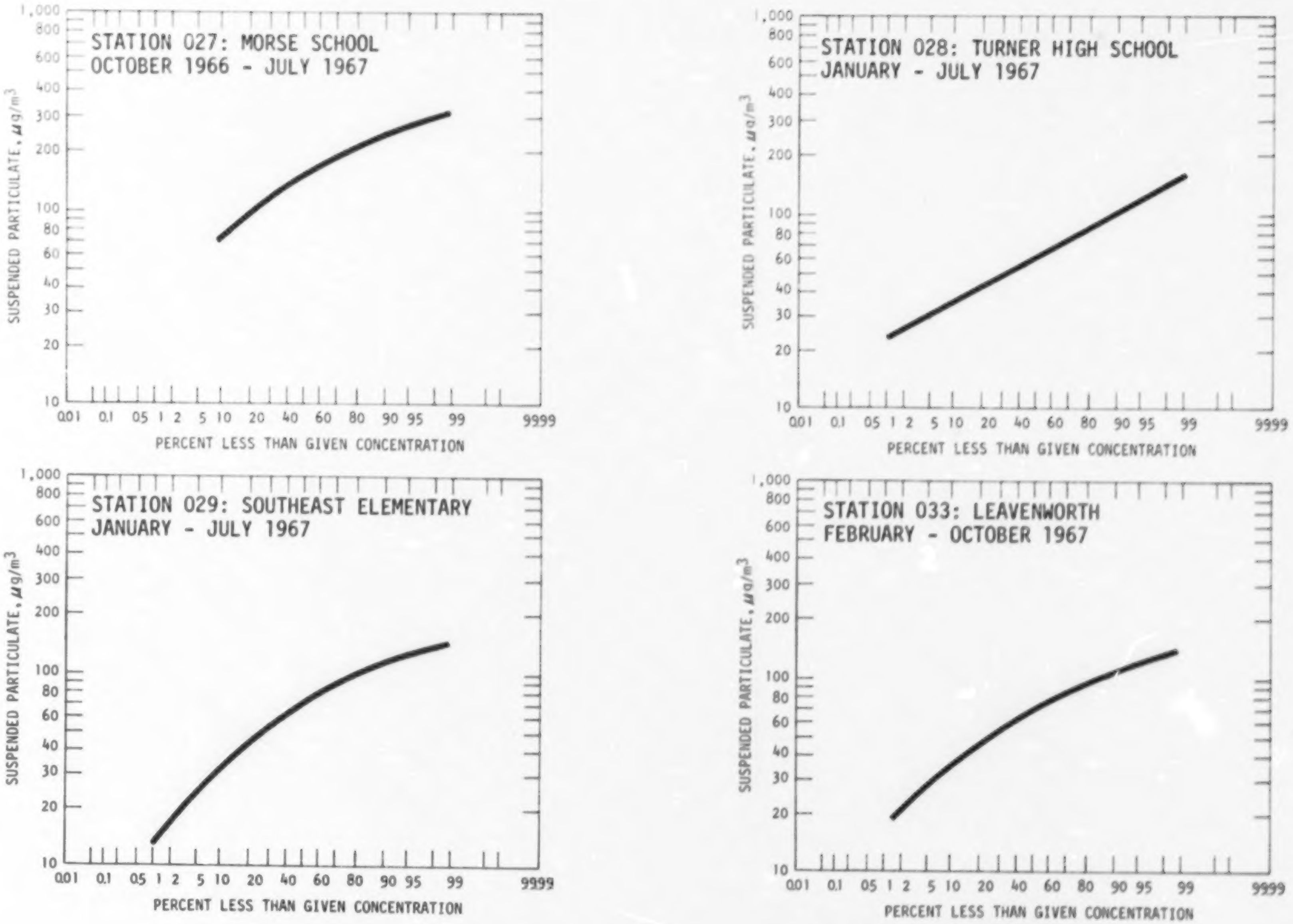


**Figure E-5.** Frequency distributions of suspended particulates - by high-volume samplers - for stations 027, 028, 029, and 033.

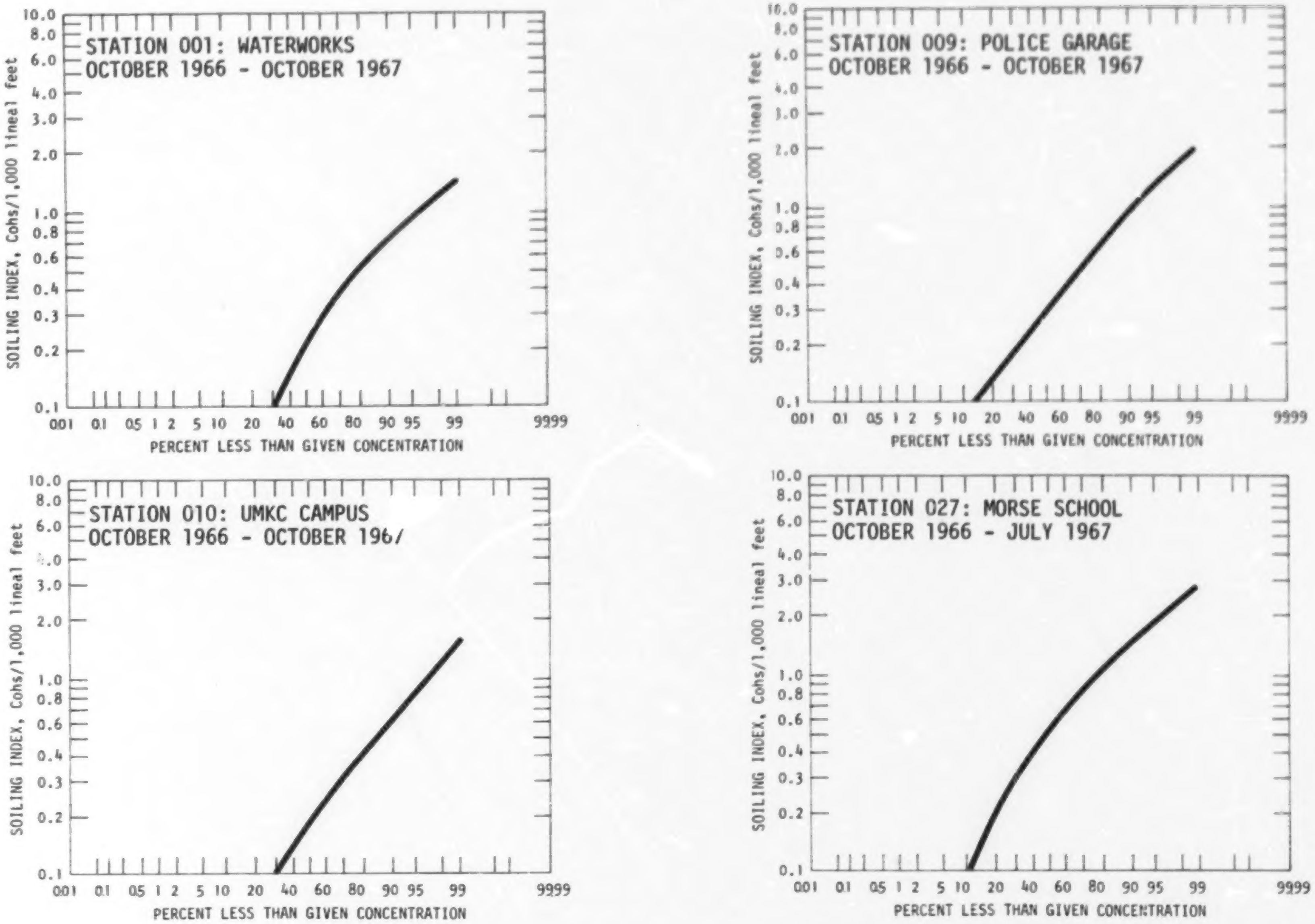


Figure E-6. Frequency distribution of suspended particulates - by AISI soiling index samplers - for stations 001, 009, 010, and 027.

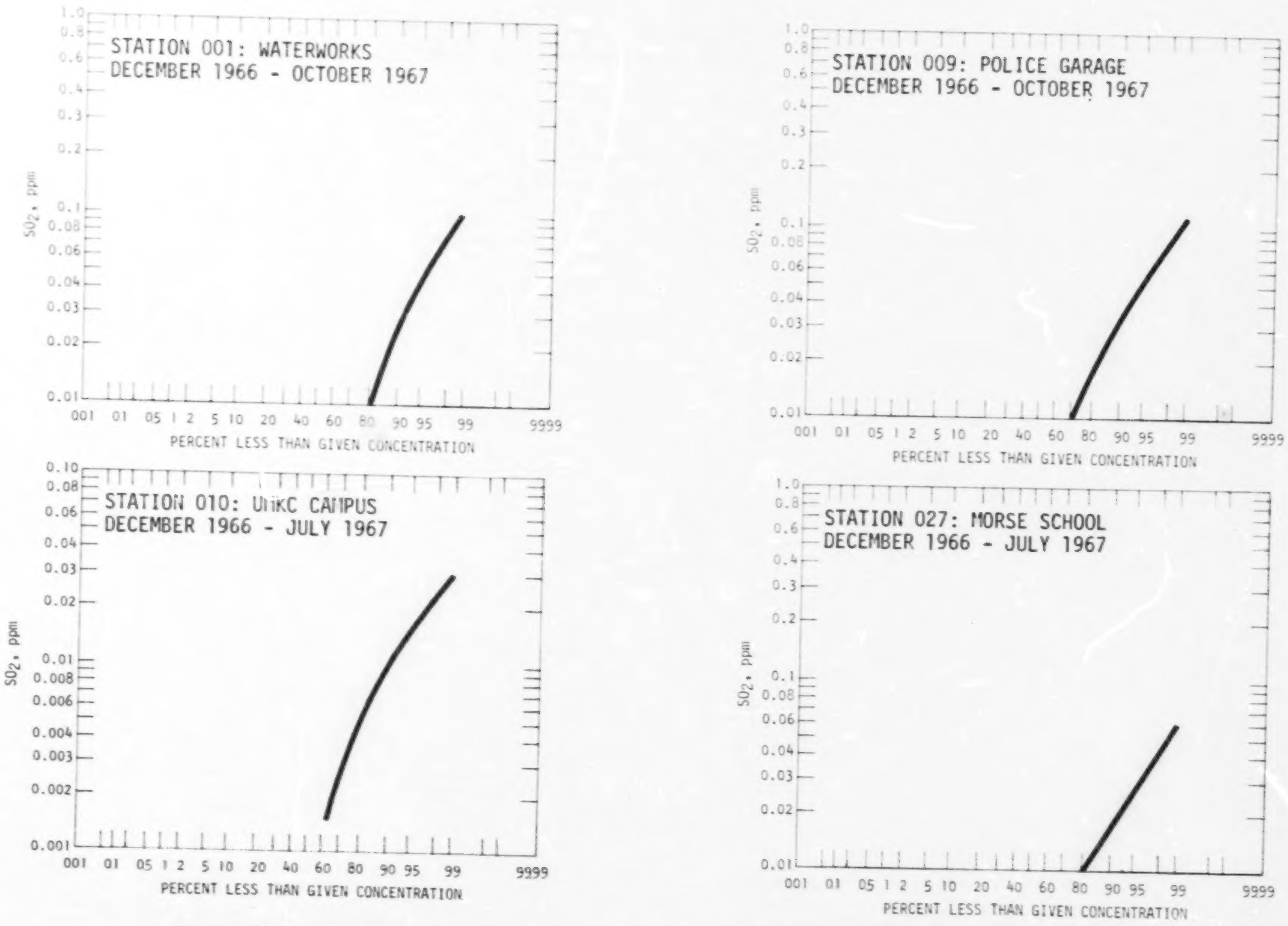


Figure E-7. Frequency distributions of sulfur dioxide for stations 001, 009, 010, and 027.